SOUTHWEST FISHERIES CENTER ADMINISTRATIVE

REPORTS, 1980

No. H-80-7 to H-80-18

LIBRARY

OCT 10 1980

ECONOMIC ANALYSIS OF HAWAII FISHERIES: A SURVEY

Linda L. Hudgins
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

October 1980

INTRODUCTION

Literature on Hawaii fisheries can generally be separated into three categories according to emphasis of the study: economic, biological, and descriptive. This report is intended to present a summary of the methodology and findings of published studies of Hawaii fisheries with an economic emphasis.[1] The first section is a review of studies which consider production and market analysis for various fisheries. The second section is a review of feasibility studies for alternative skipjack tuna baitfish.

GENERAL FISHERIES STUDIES

Rigorous economic analysis of the Hawaii fisheries essentially began with Hale's (1964) study, prepared as a background paper on which to base potential legislative fishery policies. Data used were Hawaii State Fish and Game records for the years 1948-63. Hale divides the fishery: 1) high seas, pelagic fishery including tuna and mahimahi, 2) shallow water and handline fishery, and 3) shellfish, pondfish, and other minor species. He also defines three categories of commercial fishermen: full-time (occupational) fishermen, part-time (supplemental income) fishermen, and sport fishermen. Hale also presents a description of markets for aku (skipjack tuna) and ahi (yellowfin and bigeye tunas). The method of analysis is descriptive which includes tabulation of vessel numbers, fishing employment, annual catch, and value of various species, from which he arrives at the conclusion that "the industry will vanish as a viable economic activity in the near future." This conclusion is based on continuation of observed trends in the fishery: 1) downward trend in the number of powered fishing vessels, 2) decline in number of fishermen, 3) declining value of total catch, and 4) lower personal income of fisherman relative to other skilled occupations.

Given this conclusion, he suggests to the legislature possible courses of action. The first would be to do nothing, allowing the industry to decline naturally. The fishing industry is no different from any other in a free enterprise system operating under principles of profit maximization. The natural decline of the industry would release resources to higher valued, more efficient uses.

Given past legislative actions which indicate the legislature's unwillingness to allow the industry to die naturally, Hale recommends a comprehensive effort to expand the fishery (as opposed to attempting short-term solutions). This recommendation is justified on the grounds that local production must compete with foreign production which is governmentally subsidized. Hale suggests the establishment of a loan program to encourage new capital; a new location for the fish market; advertising to increase demand; improved marketing strategies; and stabilization of fishermen's income. He

---

[1]Unpublished reports are listed in the bibliography for completeness but are not reviewed here.

points out the need for increased research on consumer demand, canned tuna demand, vessel design, and storage facilities.

Shang (1969) attempts to determine the important factors that are responsible for the lack of growth of the industry. Data used were from State Fish and Game for 1953-66. Shang's methodology was a cost-revenue analysis based on estimated annual vessel catch (885,000 lb) and estimated average costs of fishing operations. The cost-revenue method was used after analysis showed that the decline in catch could not be attributed to a change in fishing conditions over time. Shang estimated both the present value and internal rate of return. He presented tabulations of the estimated minimum ex-vessel price required for various initial investments in a vessel, and the internal rates of return on investment based on various ex-vessel price levels.

Shang estimated three sets of demand functions. The first, an aggregate demand of the cannery and fresh fish market faced by producers, resulted in a demand elasticity of -5.5. This high elasticity resulted from the almost perfectly elastic cannery demand. The second, a cannery demand, showed: a) the monthly ex-vessel price of yellowfin tuna in Hawaii is determined by the Japanese export price of yellowfin tuna, and b) a high positive correlation ($R^2 = 0.98$) between the west coast prices of yellowfin tuna and the Hawaii price of skipjack tuna. The third set of demand functions are for the fresh fish market: one for the peak fishing season and one for the off-season. In both, price was a significant determinant of the monthly quantity sold. However, less than one-third of the quantity variation was explainable by either function. Shang states that "reliable data on price and quantity demanded of fresh skipjack tuna is scarce. The levels of price used here are the average selling prices from the Hawaiian Tuna Packers" (Shang 1969:83).

Shang explains the stagnation of the local tuna industry by the low, relatively stable price of tuna and by the increasing costs of fishing, which together result in a low profit margin. Given his cost-revenue analysis, Shang suggests that if tuna production could be increased by at least 50%, investment would be profitable even if the annual price level was as low as 10.8 cents per pound. Possible means of achieving this level of productivity would be through decreased bait mortality, increased information on the probability distribution of fish, or the adoption of new fishing technology.

Shang's study was the first to employ econometric techniques in analysis of a Hawaii fishery. Whereas Hale suggested the State vessel loan program, Shang analyzed the effects of the program and examined market potential, cost factors, and the impact of imports. His study was based on average ex-vessel prices and estimated costs which were the best available data at the time.

Ahsan et al. (1972) assessed the cost-earning situation for both the aku and ahi fleets. The study was conducted for 1971 using cost-earning data derived primarily from survey information. Historical State Fish and Game catch and revenue data were presented for 1960-70. The methodology was application of standard budgeting techniques.

Digitized by the Internet Archive
in 2025

https://archive.org/details/administrative-report-h_1980_7-18

The average earnings of boat owners and crew members were estimated. For aku boat owners, the average annual income before taxes was $20,691 for high-earning boats, $9,258 for average-earning boats, and $4,269 for low-earning boats. The estimated hourly wages of aku fishermen was $1.71. For ahi boat owners, the average annual income before taxes was $5,565 for high-earning boats, $1,039 for average-earning boats, and -$2,030 for low-earning boats. The estimated average annual income for ahi fishermen was $4,422, $3,548, and $1,837 for high, average, and low-earning boats, respectively. Ahsan et al. conclude that low earnings relative to other occupations and limited markets are the major factors restricting the expansion of the industry.

This conclusion is consistent with prior research indicating that relatively high costs are an inhibiting factor for entry into the industry. The authors, however, contradict Shang's finding by asserting that limited markets are a constraint. Their study, which addressed questions of production costs, does not permit any statements concerning market demand conditions.

Hoffman and Yamauchi (1972) undertook a comprehensive survey and analysis of the State's recreational fisheries. The study presented the first detailed estimates of fisherman participation, characteristics, and expenditures on recreational fishing. The selection of population and sampling technique are described in detail.

Total estimated number of fishermen in the State was 122,400 with about 75% from the City and County of Honolulu. Distribution of this participation was 68% from shoreline fishing, 12% fishing from a boat, and 10% fishing while diving. The study also presented the following characteristics of the Hawaii recreational fisherman--51% were head of household and 50% were between 12 and 32 yr of age. The major ethnic groups of fishermen were 37% Japanese and 22.4% Caucasian. Forty-six percent of all fishermen had completed high school and an additional 32.7% had "some college" or had completed college. Furthermore, 40.3% classified themselves in a $2,000-$5,999 income category and 48.4% were regularly employed as federal employees, retail and wholesale personnel, or as students.

Hoffman and Yamauchi estimated about 4.3 million total fishing days taken per year with two-thirds of these days taken by fishermen from the City and County of Honolulu. The statewide average annual fishing days per fisherman was calculated as 35.8 with wide variation about this mean by County. Of the total days fished, 90.7% involved saltwater fishing. Maps were presented showing preferred fishing areas around each County.

Lastly, the economic impact of recreational fishing expenditures on Hawaii State income was calculated. Annual expenditures were estimated at about $16.1 million or about $132 per year per fisherman. Expenditures on equipment accounted for about 40% of the total. The total multiplier impact on State income was calculated as $11.5 million annually, after leakages were taken into account.

Hoffman and Yamauchi clearly describe the methodology and limitations of their study. They also suggest areas for future research on recreational fisheries.

Comitini's (1977) study was the first to use the production function approach to analyze the behavioral characteristics of the industry. Comitini utilized new State Fish and Game data on catch levels, average price, and vessel characteristics. This study considers trips per vessel, mortality of baitfish, and value of catch per vessel for the years 1949-72. Regression methods were used in the estimation of a Cobb-Douglas production function model.

Capital was measured two ways: (a) as the gross tonnage of each vessel, and (b) as the annually depreciated capital value of each vessel. Seasonality of catch and qualitative characteristics of the vessels were also considered using the dummy variable method. Comitini's results show that 1) using gross tonnage as a measure of capital input is inferior to using depreciated capital value; 2) natural fluctuations in resource availability are significant and should be considered; 3) vessels are not homogenous as indicated by the significance of the vessel dummy variables. A linear relationship was also estimated. From this, Comitini derived an "index of fishing effectiveness" and expected catch. This index captures differences in vessel that had not previously been evaluated. Specifically, the study cites differences in entrepreneurial ability and strategy of fishing. The computation of marginal products and relative shares of labor and capital indicate that these shares are not significantly different from the traditional 60:40 split of the catch observed in the fishery. Comitini concludes that "the major constraints to Hawaiian skipjack tuna fisheries development lie in the skipjack tuna resource potential relative to the opportunity costs of capital and labor, and also the costs of obtaining baitfish" (Comitini 1977:40). He recommends two solutions to the apparent stagnation of the industry: 1) shift to a higher production ray through a change in fishing technique or 2) move along the same production ray but reduce bait mortality so that production can be increased from current techniques.

On the demand side, Garrod and Chong (1978) provide a description of the major structural characteristics of the fresh fish market in Hawaii. Specifically, they examine the hypothesis that the market is not operating in a manner conducive to expansion. They present tabulated data on a number of industry characteristics.

Garrod and Chong also describe in detail the market structure and practices. They analyze structural attributes of the market which may be "conducive to misconduct, high prices, low efficiency, poor product quality, and a general low standard of performance" (Garrod and Chong 1978:18). In particular, they assess the following three attributes: ease of entry into the market, degree of buyer and seller concentration, and absolute number of firms.

They conclude that barriers to entry may exist because the market is well established. The new entrant faces normal economic barriers as well as the requirement to compete against the goodwill and marketing know-how

of the established firm. They develop a concentration index at the wholesale level based on number of employees of each firm. Garrod and Chong conclude that, given the small number of wholesalers and the fact that number of employees is a poor proxy for market share, their concentration index does not provide evidence of a concentrated market. They suggest, however, that the small number of firms may imply the presence of market leadership. Using the absolute number of firms as a measure, Garrod and Chong describe the market as oligopolistic and oligopsonistic.

The discussion on price determination in the fresh fish market is apparently based on interviews with fish dealers and observations at the various market outlets. Garrod and Chong consider factors not previously given much attention in market analysis. For example, they point out that: 1) the fish dealers generally set their prices on the basis of the morning auction price; 2) that price varies by species and conversion rate (percent of whole fish that is saleable); 3) that availability of proper storage and perishability of the fish are important in price determination especially at the end of the day; 4) that the minimum negotiated price for aku has benefited the aku fisherman and could serve as an example to other fishermen; and 5) that allegations of collusion among large buyers "could not be verified empirically" (Garrod and Chong 1978:21).

Lastly, they consider alternative marketing systems and present a "scenario" which might develop if adoption of modern technology occurred. They suggest that cost-reducing innovations often result in fewer persons producing more, that is, a more concentrated market (Garrod and Chong 1978:23). This result is because the increased volume of fish available for sale would force price down, driving less efficient firms out of the industry. Their final observation is that markets evolve to meet the situation and that the existing market structure may be the most viable.

Garrod and Chong are the first to attempt an industry or market study, and lay a theoretical framework for a study of the market, with consideration of both demand and supply. Data are lacking to actually test many of the questions posed by Garrod and Chong.

Although the research area of the above studies is the same, there are variations in emphasis and methodology. Generally, the authors have attempted to describe the fishery and explain why there has been no entry or expansion. The conclusions consistently point to increasing costs and market limitations as reasons for the "declining" or "stagnating" industry. There have also been allusions both in the economic studies and the descriptive literature to some type of "sinister" collusion in the fresh fish market. Garrod and Chong propose that the existence of collusion (which they were unable to verify empirically) may be a result of natural evolutionary tendencies within the market.

Both cost and market analyses for skipjack tuna have used the average price derived from Hawaii State Fish and Game data. Finally, except for Garrod and Chong, the emphasis of the previous research has been on the supply side. To date, supply and demand have not been empirically or

theoretically analyzed together.[2] Hoffman and Yamauchi presented the first major background information on which to base analysis of the recreational fisheries.[3]

BAITFISH STUDIES

Shang and Iversen (1971) present an economic feasibility study for the production of threadfin shad as a live bait for Hawaii's skipjack tuna fishery. They estimate a break-even price for nehu, Stolephorus purpureus, the major baitfish species used in the fishery. The calculation of this price is based on the income foregone to fishermen when they are fishing for bait instead of fishing for skipjack tuna. They estimate a break-even (maximum) price of nehu per bucket as $12.70 (year-round), $13.80 (peak fishing months), and $11.00 (other fishing months). Catch rates with either nehu or shad are about equal but shad has about a 10% lower mortality rate than nehu, which increases returns to a bucket of shad bait. The estimated break-even (maximum) price of shad if $14.60 and $13.80 (year-round), $15.90 and $15.00 (peak fishing months), and $12.60 and $12.00 (other fishing months) using 10 and 16% mortality of shad, respectively.

Using present-value analysis, estimates of production break-even (minimum) prices are presented for 10 and 16% mortality rates. This analysis includes investment costs, operation costs, and net present value at varying discount rates. Results indicate that shad operation is feasible with an annual production of 3,660 buckets of shad per 10-acre pond unit and with the selected range of discount rates (6-14%).

Crumley (1977) considers the commercial production of tilapia, Tilapia mossambica, for use as baitfish in the Hawaiian skipjack tuna fishery. Crumley uses Shang and Iversen's formulas to reestimate the break-even price of nehu at $30.12 per bucket. He then estimates construction and operating costs of tilapia production which result in cost per bucket of tilapia of $17.56 which includes a 20% "profit" for the producer.

Herrick (1977) estimated the cost per bucket for production of the topminnow, Poecilia vittata, for use as a baitfish in the Hawaii skipjack tuna fishery. This study is based on depreciated annual capital costs plus operating costs for outputs of 3,000 bucket/yr output and 30,000 bucket/yr output. The topminnow has not been proven to be as effective as nehu. Estimated production costs were $12.93 per bucket and $3.69 per bucket for 3,000 and 30,000 bucket/yr, respectively.

---

[2]See Hudgins (1980a) for market model of Hawaiian skipjack tuna.

[3]See Adams (1980) for recent recreational fisheries research.

BIBLIOGRAPHY

Adams, M. F.
1978. Alternative estimates of net economic benefits for billfish-tuna recreational-commercial fishermen in Kailua-Kona, Hawaii. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Admin. Rep. 18H, 10 p.

1980. A multispecies household production analysis of recreational fishing with dispositional benefits. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Admin. Rep. H-80-5, 26 p.

Ahsan, A. E., J. L. Ball, and J. R. Davidson.
1972. Costs and earnings of tuna vessels in Hawaii. Univ. Hawaii Sea Grant Program, UNIHI-SEAGRANT-AR-72-01, 22 p.

Comitini, S.
1977. An economic analysis of the State of the Hawaiian skipjack tuna fishery. Univ. Hawaii Sea Grant Tech. Rep. UNIHI-SEAGRANT-TR-78-01, 46 p.

Cooper, J. C., and M. F. Adams.
1978. Preliminary estimates of catch, sales, and revenue of game fish for the fishery conservation zone around the main Hawaiian Islands, by types of troll and longline vessels and by species, 1976. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Admin. Rep. 24H, 10 p.

Crumley, B. L.
1977. A commercial tilapia, Tilapia mossambica, hatchery for Hawaiian skipjack tuna, Katsuwonus pelamis, fishery--cost analysis and problematical study. In R. S. Shomura (editor), Collection of tuna baitfish papers, p. 137-148. U.S. Dep. Commer., NOAA Tech. Rep., NMFS Circ. 408.

Garrod, P. V., and K. C. Chong.
1978. The fresh fish market in Hawaii. Hawaii Agricultural Experiment Station, Coll. Trop. Agric., Univ. Hawaii, Honolulu, 24 p.

Hale, E. A.
1964. Economic investigation of the commercial fishing industry in the State of Hawaii. Progress Report. Department of Planning and Economic Development, State of Hawaii, Honolulu, 39 p.

Herrick, S. F., Jr.
1977. Some economic and technological aspects related to commercial production of the topminnow, Poecilia vittata. In R. S. Shomura (editor), Collection of tuna baitfish papers, p. 157-159. U.S. Dep. Commer., NOAA Tech. Rep., NMFS Circ. 408.

Hoffman, R. G., and H. Yamauchi.
1972. Recreational fishing. Its impact on state and local economies. Hawaii Agricultural Experiment Station. Coll. Trop. Agric., Univ. Hawaii, Dep. Pap. 3, 38 p.

Hudgins, L. L.
1980a. An econometric model of a fisheries market with endogenous supply: The Hawaii skipjack tuna case. Ph. D. Dissertation. Univ. Hawaii, Honolulu, 114 p.

1980b. Per capita annual utilization and consumption of fish and shellfish in Hawaii, 1970-77. Mar. Fish. Rev. 42(2):16-20.

McCoy M.
1973. A study of the training potential in Hawaii to provide fishing and processing methods training to citizens and fishery development officers of the central and western Pacific. Res. Corp. Univ. Hawaii, Project No. 891, Honolulu, 33 p.

Peterson, S. B.
1973. Decisions in a market: A study of the Honolulu fish auction. Ph.D. Dissertation. Univ. Hawaii, Honolulu, 287 p.

Shang, Y. C.
1969. The skipjack tuna industry in Hawaii: Some economic aspects. Econ. Res. Cent., Univ. Hawaii, 59 p.

Shang, Y. C., and R. T. B. Iversen.
1971. The production of threadfin shad as a live bait for Hawaii's skipjack tuna fishery: An economic feasibility study. Econ. Res. Cent., Univ. Hawaii, 42 p.

Skillman, R. A., and F. V. Riggs.
1978. Historical trends in catch, fishing effort, and catch per unit effort in the Hawaiian fishery for skipjack tuna, Katsuwonus pelamis 1948-76. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Admin. Rep. 7H, 10 p.

MAY 1 1980

INDO-PACIFIC FISHERY COMMISSION

19TH SESSION
SYMPOSIUM ON THE DEVELOPMENT AND MANAGEMENT OF SMALL-SCALE FISHERIES

Kyoto, Japan, 21-23 May 1980

COUNTRY STATUS REPORT

ON

UNITED STATES OF AMERICA

(Small-Scale Fisheries in the U.S.A.)[1]

May 1980

[1]By Howard O. Yoshida, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, Hawaii 96812.

COUNTRY STATUS REPORT
ON
UNITED STATES OF AMERICA
(Small-Scale Fisheries in the U.S.A.)

CONTENTS

		Page
1.	Introduction	3
2.	Present Situation	6
	2.1 Economic role of fishing industry	6
	2.2 Resource availability	6
	2.3 Production	6
	2.4 Utilization, consumption, and trade	7
	2.5 Marketing, distribution, and physical infrastructures	7
	2.6 Administration and institutional structure	7
3.	The Present Role, Future Scope, and Development Priorities of Small-Scale Fisheries	7
4.	References	8

COUNTRY STATUS REPORT ON UNITED STATES OF AMERICA

(Small-Scale Fisheries in the U.S.A.)

1. INTRODUCTION

If the magnitude of a problem can be equated to the amount of attention it has received, then the small-scale fisheries in the United States of America have not posed much of a problem, at least on the surface. Small-scale fisheries as an entity have not been treated in the published literature. A preliminary analysis of small-scale or "artisan" fisheries conducted by the International Center for Marine Resources Development, University of Rhode Island, did not include any small-scale fisheries in the U.S.A. (University of Rhode Island, 1975).

This is not to say that there are no small-scale fisheries or fishermen in the U.S.A. Small-scale fisheries and fishermen have been characterized as those having small capital investment in each unit including a correspondingly low level of organization. The boats in these fisheries are predominantly individually owned and fishing methods are labor-intensive and unmechanized. These fisheries usually require little specialized mechanical skills; however, good seamanship may be required. Productivity and incomes are low in small-scale fisheries and catches are sold in local markets or even on a commercial barter basis; thus, infrastructural backing and credit are usually lacking (Proude, 1973). These descriptions and characteristics of small-scale fisheries and fishermen probably fit many small fisheries and fishermen in the U.S.A. The world total of full- and part-time small-scale fishermen has been estimated at 10 to 15 million (Proude, 1973; University of Rhode Island, 1975). It is not clear, however, whether these totals include fishermen in the U.S.A. The number of fishermen on boats (see discussion under section 2.3) in Alaska, California, Hawaii, Oregon, and Washington in 1975 was estimated at 24,296 (Table I).

In the developed country (such as the U.S.A.) the small-scale fishery sector generally consists of purely local fisheries that are poorly developed (in the economic sense) and are located in a setting of well utilized natural resources and plentiful supply of capital and skilled labor. Alternatively, it may include many part-time fishermen who either have alternative employment or are exploiting particularly valuable species (Proude, 1973).

Because fisheries in the U.S.A. have not been analyzed in terms of the categorization, "small-scale fisheries," it is difficult to determine their status. However, the status of U.S.A. fisheries in general will be briefly discussed and an attempt will be made to discuss some examples of what may be considered small-scale fisheries in the states of the U.S.A. bordering or in the Pacific Ocean.

Table I. 1975 Operations of Selected "Small-Scale" Fisheries in Alaska, California, Hawaii, Oregon, and Washington (Source: [U.S.] National Marine Fisheries Service, 1978)

OPERATING UNITS

	Alaska	California	Hawaii	Oregon	Washington	Total
			Number			
Fishermen						
On boats and shore						
Full-time	7,067	7,769	2,197	1,628	5,278	23,939
Part-time	--	--	--	18	339	357
Total	7,067	7,769	2,197	1,646	5,617	24,296
Boats						
Motor	4,195	2,832	1,278	1,571	4,505	14,381
Other	--	364	--	--	--	364
Total	4,195	3,196	1,278	1,571	4,505	14,745

LANDINGS STATISTICS

Fishery	Landings: Weight (metric ton)	Landings: Ex-vessel value ($)	No. of boats in fishery	Species caught
		Alaska		
Anchor, set, or stake gill net	9,517.1	7,896,191	2,384	Sea herring and salmon
		California		
Common haul seine	267.4	75,629	20	Surf or silver smelt
Oyster rake	362.9	1,105,504	76	Oysters
"By hand"	21.2	41,549	8	Oysters, sea mussels, clams
		Hawaii		
Various	317.0	354,725	284	All species combined

Table I. Continued.

Fishery	Landings: Weight (metric ton)	Landings: Ex-vessel value ($)	No. of boats in fishery	Species caught
		Oregon		
Anchor, set, or stake gill net	285.8	446,261	33	Salmon, steelhead trout, common sturgeon, shad, striped bass
Drift gill net	63.8	21,296	9	Shad
Common dip net	35.6	5,885	4	Lamprey, shad, lingcod
		Washington		
Pot	1.3	2,220	5	Freshwater crawfish
Anchor, set, or stake gill net	464.3	849,032	54	Lingcod, salmon, shad, common sturgeon, smelt
Drop dip net	0.1	189	4	Dungeness crab
Drift gill net	8.8	1,520	30	Shad

2. PRESENT SITUATION

2.1 Economic role of fishing industry

Recently, a study was published which expressed the sales and consumption of U.S.A. fishery products in value terms, which is more meaningful when comparisons are made with gross national product (GNP) and total food consumption (Penn and Crews, 1979). Penn and Crews computed the following value added (contribution to the economy as GNP) figures for edible fishery products in the U.S.A.: 1976, $5.083 billion; 1977, $5.558 billion; and 1978, $6.378 billion, which include fishery products from domestic and imported sources. It would have been useful to have the contribution of small-scale fisheries to these figures but Penn and Crews did not make such computations.

In comparison with certain selected industry groups (agriculture and forestry) the U.S.A. fishing industry contributed $840 million (1.75%) in 1976 and $950 million (1.75%) in 1977 to the combined GNP of the agriculture, forestry, and fishing industries at the harvesting level. Seafood's share of total expenditures for food amounted to $9.57 billion (4.23%) in 1976, $10.31 billion (4.20%) in 1977, and $11.45 billion (4.25%) in 1978. These expenditures for seafood represented 0.81% in 1976, 0.79% in 1977 and 0.79% of the disposable personal income in the U.S.A. (Penn and Crews, 1979).

2.2 Resource availability

The eight regional Fishery Management Councils created under the provisions of the Fishery Conservation and Management Act (FCMA) of 1976 are in the process of preparing Fishery Management Plans for various marine species in the 200-mile Fishery Conservation Zone (FCZ) of the U.S.A. The FCMA requires estimates of maximum sustainable yield (MSY) for all species under management. As MSY estimates become available, better estimates of the total magnitude of marine resources in the FCZ should be obtained.

Fishery production figures can provide an idea of the magnitude of the resources. In 1978 the U.S.A catch was 2.6 million metric tons, a new record. In the same year the foreign catch in the FCZ amounted to 1.8 million metric tons ([U.S.] National Marine Fisheries Service 1978).

2.3 Production

The fishery statistics of the U.S.A. do not allow an accurate separation of landings made in small-scale fisheries and large-scale fisheries. Many species of fishes are the targets of vessels or boats in both the small-scale and large-scale fisheries sectors. Without more detailed information on the various fisheries it is also not possible to determine whether the fishery, vessels or boats, and fishermen do or do not fit the characteristics of "small-scale" as

presented earlier. However, certain statistical summarizations are given in terms of the categories "vessels," which are defined as fishing crafts having a net carrying capacity of greater than 5 tons, and "boats," which are defined as those having a net carrying capacity of less than 5 tons (see for example ([U.S.] National Marine Fisheries Service, 1978). Assuming that fishing crafts categorized as boats are in the small-scale fishery sector, it was possible to isolate certain U.S.A. fisheries that border on the Pacific Ocean for examination (Table I). It can be seen that the landings in these fisheries ranged from a low of 0.1 metric ton to a high 9,517.1 metric tons having an ex-vessel value ranging from $189 to $7,896,191.

2.4 Utilization, consumption, and trade

The total U.S.A landings of fish from the Pacific Ocean in 1975 were 707,880 metric tons. Of this total 541,006 metric tons (76.4%) were used for human food and 166,874 metric tons (23.6%) were used for industrial purposes. The industrial products included fresh and frozen animal food, fresh and frozen bait, canned animal food and fish meal, oil and other solubles. The per capita consumption of commercially caught fish and shellfish was 5.5 kg of fish (edible weight) in 1975. In 1975 exports of domestic edible fishery products totaled 98,976 metric tons, which was valued at $267.4 million ([U.S.] National Marine Fisheries Service, 1978).

2.5 Marketing, distribution, and physical infrastructures

In general, the U.S.A. has a well developed marketing, distribution, and physical infrastructure. To aid the industry in this regard, ongoing economic analyses of fishery products are provided in the "Market Review and Outlook" and the "Fishery Market News Report" published by the National Marine Fisheries Service and in the "National Food Review" published by the U.S. Department of Agriculture ([U.S.] National Marine Fisheries Service, 1979).

2.6 Administration and institutional structure

The National Oceanic and Atmospheric Administration (NOAA) is the principal agency in the U.S.A responsible for living marine resources and the National Marine Fisheries Service is the primary NOAA entity responsible for regulating, managing, and protecting these resources. ([U.S.] National Marine Fisheries Service, 1979).

3. THE PRESENT ROLE, FUTURE SCOPE, AND DEVELOPMENT PRIORITIES OF SMALL-SCALE FISHERIES

The objectives and methods of small-scale fisheries development in undeveloped and developed countries were discussed by Proude (1973). Proude stated that the introduction of assistance to small-scale fisheries in developed countries is usually of recent origin. Governments in developing countries, including the U.S.A., devised policies to (a) improve the

efficiency of production and distribution and thereby reduce costs to increase income and profitability, and (b) maintain the contribution of fisheries to national food supplies and the export trade, and increase the attractiveness of fishery products for domestic and foreign consumers.

4. REFERENCES

Penn, E.S. and Crews, W.J. Value added, margins, and consumer expenditures
1979 for edible fishery products in the United States, 1976-78. Mar. Fish.Rev., 41(12):p.1-9.

Proude, P.D. Objectives and methods of small-scale fisheries development.
1973. J.Fish.Res.Board Can., 30(12):p.2190-2195.

[U.S.] National Marine Fisheries Service. Fishery statistics of the United
1978 States, 1975. U.S.Dep.Commer., NOAA, Natl.Mar.Fish.Serv., Statist.Dig. 69, 418 p.

[U.S.] National Marine Fisheries Service. Report of the National Marine
1979 Fisheries Service for the calendar year 1978. U.S.Dep.Commer., NOAA, Natl.Mar.Fish.Serv., 60 p.

University of Rhode Island. Artisan fisheries, characteristics, problems,
1975 needs and relationships to aquaculture. Preliminary analyses by the International Center for Marine Resources Development, University of Rhode Island. 55 p.

EXPLOITATION OF NORTH PACIFIC ALBACORE BY KOREAN AND TAIWANESE LONGLINERS BASED IN AMERICAN SAMOA

Jerry A. Wetherall
and
Marian Y. Y. Yong
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

June 1980

Prepared for Fifth North Pacific Albacore Workshop, La Jolla, California, 30 June-3 July 1980.

EXPLOITATION OF NORTH PACIFIC ALBACORE BY KOREAN AND TAIWANESE LONGLINERS BASED IN AMERICAN SAMOA

Jerry A. Wetherall
and
Marian Y. Y. Yong

Background

Tuna longliners based in Pago Pago, American Samoa, have traditionally exploited tuna stocks in the South Pacific and in equatorial waters between long. 150°E and 120°W. South Pacific albacore have been the principal target species, particularly for Japanese vessels (which operated out of Pago Pago until 1973) and for Taiwanese boats. As a rule these vessels focused on fishing grounds south of the equator, and did not venture north of about lat. 10°N. However, in the mid-1970's they extended their range of activity in the North Pacific. For example, a Korean longliner based in American Samoa reported extensive fishing north of lat. 35°N on a 4-month trip beginning and ending in Pago Pago.

The expansion of fishing by these vessels into the North Pacific is still insignificant in terms of its impact on North Pacific albacore stocks, and can safely be neglected in stock assessments and fishery appraisals. Nevertheless, it is worth mentioning for the sake of completeness and because it might be rather unexpected in light of recent hikes in the price of fuel. The purpose of this note is therefore to briefly summarize the available statistics on the catch and effort by American Samoa-based longliners in the North Pacific during the period 1965-1978.

Data Sources

The catch and effort statistics for American Samoa-based longliners are derived from two sources: (1) logbook records submitted by vessel captains to the Government of American Samoa, which give the location for each day of fishing along with nominal effort (hooks) and catch (number of fish, by species), and (2) cannery records furnished to us by the two tuna packing firms in Pago Pago, giving the date of unloading for each vessel trip and the quantity of fish landed. Catches in number of fish were converted to estimates of catch in weight using information on catch size composition extracted from the literature. No adjustment was made for possible incompleteness of the logbook records, so the total catch and effort estimates presented here may have a small negative bias.

Effort Distribution and Catch

Figure 1 gives the distribution of nominal effort during 1965-1972 by Japanese longliners based at Pago Pago. As the figure illustrates, Japanese vessels never fished above lat. 15°N. Further, Table 1 shows that their effort above lat. 10°N amounted to only 14 vessel days of fishing. Virtually all of the Japanese longlining north of the equator was between lat. 0°-10°N, taking mostly yellowfin and bigeye tunas in March and April.

As shown in Figures 2-5, Korean and Taiwanese longliners based at Pago Pago confined their North Pacific effort to grounds south of lat. 10°N prior to 1974 (except for 15 days of Korean fishing; Table 1). Yellowfin and bigeye predominated in the catch, this region being relatively unproductive for albacore, at least at the depths exploited by conventional longline gear (Figure 6). Korean vessels, despite their smaller fleet during this period, accounted for most of the fishing effort in the 0°-10°N area.

Beginning in 1974 the logbook records show both Korean and Taiwanese longliners extending northward, as far as lat. 37°N for one Korean boat. In the 10-20°N region the Taiwanese vessels have been far more active than Korean boats, catching predominantly albacore. Above lat. 20°N Korean vessels, being somewhat larger, have exerted more effort than Taiwanese longliners. Albacore has also been the principal species caught here. Fishing in this northern region has been concentrated in November-February, whereas the equatorial fishing takes place principally in March-May.

Size Composition

Samples of albacore landed at Pago Pago are measured by the Office of Marine Resources of the Government of American Samoa. Because the catch from a particular trip may have come from a very wide area of the ocean (especially in recent years) it is sometimes difficult to use these measurements to study spatial variation in size composition. Location of capture is assumed to be the area where most of the catch was taken. With these limitations in mind, we pooled the 499 measurements within 0-10°N; no samples were available with assigned locations north of 10°N. The resulting frequency distribution (Figure 7) is similar to those for 0-5°S and 5-10°S (Figure 8, compiled from an earlier study) with respect to mode, but suggests a relatively higher abundance of large albacore (above 100 cm) in the 0-10°N region than is seen in the corresponding area south of the equator.

Validation

Since the relatively long-range wanderings of some American Samoa-based longliners has been a surprise to many observers, in summarizing these statistics we were particularly careful to check the validity of reported fishing locations. As revealed in Figure 3, compiled from unscreened data, a small number of logbook records report longlining effort in the middle of the Australian outback, an area which has seen no marine life since the Silurian Period. Although such obvious errors are rare, how can one be sure of reported fishing locations in areas where fishing is feasible? We were especially concerned about the reported fishing activity above lat. 20°N. A total of 17 vessel trips reported fishing this far north. In some of these cases it was clear that the vessel in question was en route to Pago Pago from a home port in the western Pacific when the fishing was done. This was verified by an examination of the American Samoa cannery records together with the daily logbook statistics. In at least 12 cases, though, the vessel's trip originated and ended in Pago Pago, and there was nothing on the source data sheets to suggest erroneous reporting of fishing location. Personal communications between the Honolulu Laboratory data manager and cannery officials in Pago Pago substantiated the occurrence of some fishing activity above lat. 20°N, so we believe the North Pacific statistics summarized here are reliable.

Table 1.--A summary of tuna fishing statistics for American Samoa-based longliners operating in the North Pacific, 1966-1978.

		Nominal effort (Vessel days)			Catch of albacore (MT)			Catch of yellowfin tuna (MT)			Catch of bigeye tuna (MT)		
Lat.	Year	Taiwan	Korea	Japan	Taiwan	Korea	Japan	Taiwan	Korea	Japan	Taiwan	Korea	Japan
0°-10°N	1966	--	--	21	--	--	0	--	--	33	--	--	11
	1967	--	102	52	--	4	0.8	--	100	48	--	74	26
	1968	--	--	10	--	--	0.5	--	--	9	--	--	3
	1969	20	251	163	1	5	3	84	305	254	9	200	120
	1970	3	95	96	0.4	6	2	2	167	214	4	73	72
	1971	34	161	--	1	7	--	83	238	--	6	142	--
	1972	22	353	10	0.8	16	0.1	25	534	11	12	312	8
	1973	2	390	--	0	7	--	2	341	--	0.3	225	--
	1974	61	712	--	0.1	10	--	62	645	--	17	370	--
	1975	12	292	--	0.5	9	--	2	149	--	2	180	--
	1976	14	115	--	3	4	--	13	139	--	3	132	--
	1977	55	75	--	7	3	--	96	91	--	1	78	--
	1978	--	286	--	--	4	--	--	384	--	--	186	--
10°-20°N	1966	--	--	--	--	--	--	--	--	--	--	--	--
	1967	--	4	4	--	4	0.06	--	7	0.3	--	3	4
	1968	--	--	--	--	--	--	--	--	--	--	--	--
	1969	--	--	--	--	--	--	--	--	--	--	--	--
	1970	--	--	10	--	--	0.3	--	--	11	--	--	9
	1971	--	--	--	--	--	--	--	--	--	--	--	--
	1972	--	11	--	--	12	--	--	14	--	--	1	--
	1973	--	--	--	--	--	--	--	--	--	--	--	--
	1974	111	25	--	49	4	--	16	20	--	21	10	--
	1975	243	6	--	122	0.1	--	21	3	--	34	2	--
	1976	80	12	--	32	7	--	12	3	--	4	1	--
	1977	75	2	--	33	0	--	8	0.7	--	1	2	--
	1978	--	--	--	--	--	--	--	--	--	--	--	--
20°-30°N	1966	--	--	--	--	--	--	--	--	--	--	--	--
	1967	--	--	--	--	--	--	--	--	--	--	--	--
	1968	--	--	--	--	--	--	--	--	--	--	--	--
	1969	--	--	--	--	--	--	--	--	--	--	--	--
	1970	--	--	--	--	--	--	--	--	--	--	--	--
	1971	--	--	--	--	--	--	--	--	--	--	--	--
	1972	--	--	--	--	--	--	--	--	--	--	--	--
	1973	--	--	--	--	--	--	--	--	--	--	--	--
	1974	22	79	--	10	54	--	1	9	--	1	14	--
	1975	1	44	--	0	40	--	0	5	--	0.1	5	--
	1976	3	4	--	0.9	2	--	0.3	0.8	--	0.9	2	--
	1977	59	19	--	43	8	--	3	1	--	11	4	--
	1978	--	--	--	--	--	--	--	--	--	--	--	--
>30°N	1966	--	--	--	--	--	--	--	--	--	--	--	--
	1967	--	--	--	--	--	--	--	--	--	--	--	--
	1968	--	--	--	--	--	--	--	--	--	--	--	--
	1969	--	--	--	--	--	--	--	--	--	--	--	--
	1970	--	--	--	--	--	--	--	--	--	--	--	--
	1971	--	--	--	--	--	--	--	--	--	--	--	--
	1972	--	--	--	--	--	--	--	--	--	--	--	--
	1973	--	23	--	--	36	--	--	0	--	--	3	--
	1974	--	39	--	--	132	--	--	0.04	--	--	5	--
	1975	--	1	--	--	0.06	--	--	0.04	--	--	0.2	--
	1976	44	103	--	108	279	--	2	0.7	--	5	13	--
	1977	19	4	--	17	2	--	0.3	0	--	0.8	1	--
	1978	--	--	--	--	--	--	--	--	--	--	--	--

Table 1.--A summary of tuna fishing statistics for American Samoa-based longliners operating in the North Pacific, 1966-1978 (continued).

		Average vessel tonnage			Average duration of trip (days)			Average longitude			Average month of fishing		
	Year	Taiwan	Korea	Japan	Taiwan	Korea	Japan	Taiwan	Korea	Japan	Taiwan	Korea	Japan
0°-10°N	1966	--	--	340	--	--	102	--	--	169°W	--	--	Sept.
	1967	--	179	129	--	65	61	--	172°W	171°W	--	Mar.	Mar.
	1968	--	--	138	--	--	51	--	--	168°E	--	--	Mar.
	1969	110	169	156	84	71	66	169°E	166°W	164°W	Aug.	Apr.	Mar.
	1970	70	154	152	79	71	67	173°W	176°W	169°W	Jan.	May	Apr.
	1971	116	159	--	79	69	--	161°E	174°W	--	Sept.	Mar.	--
	1972	168	182	111	94	93	40	175°E	170°W	178°W	Mar.	May	Mar.
	1973	140	205	--	86	116	--	157°E	178°W	--	Apr.	July	--
	1974	145	207	--	92	117	--	164°E	172°W	--	Aug.	Apr.	--
	1975	168	195	--	88	114	--	178°W	174°W	--	Mar.	Mar.	--
	1976	163	224	--	120	112	--	174°E	178°E	--	Dec.	May	--
	1977	182	217	--	128	119	--	177°W	177°W	--	Jan.	May	--
	1978	--	185	--	--	120	--	--	180°E	--	--	Mar.	--
10°-20°N	1966	--	--	--	--	--	--	--	--	--	--	--	--
	1967	--	184	99	--	80	38	--	146°E	161°W	--	Mar.	Mar.
	1968	--	--	--	--	--	--	--	--	--	--	--	--
	1969	--	--	--	--	--	--	--	--	--	--	--	--
	1970	--	--	138	--	--	59	--	--	172°W	--	--	Apr.
	1971	--	--	--	--	--	--	--	--	--	--	--	--
	1972	--	143	--	--	70	--	--	154°W	--	--	June	--
	1973	--	--	--	--	--	--	--	--	--	--	--	--
	1974	145	224	--	91	115	--	178°E	169°E	--	Aug.	June	--
	1975	151	197	--	89	90	--	175°E	169°E	--	Feb.	Apr.	--
	1976	175	254	--	122	162	--	172°E	161°E	--	Aug.	Mar.	--
	1977	170	226	--	137	140	--	173°E	158°W	--	Feb.	Jan.	--
	1978	--	--	--	--	--	--	--	--	--	--	--	--
20°-30°N	1966	--	--	--	--	--	--	--	--	--	--	--	--
	1967	--	--	--	--	--	--	--	--	--	--	--	--
	1968	--	--	--	--	--	--	--	--	--	--	--	--
	1969	--	--	--	--	--	--	--	--	--	--	--	--
	1970	--	--	--	--	--	--	--	--	--	--	--	--
	1971	--	--	--	--	--	--	--	--	--	--	--	--
	1972	--	--	--	--	--	--	--	--	--	--	--	--
	1973	--	--	--	--	--	--	--	--	--	--	--	--
	1974	150	235	--	119	173	--	164°W	162°W	--	July	June	--
	1975	164	250	--	76	88	--	172°W	157°W	--	Jan.	Feb.	--
	1976	207	229	--	121	148	--	175°W	162°W	--	Dec.	Dec.	--
	1977	189	229	--	129	148	--	163°W	162°W	--	Jan.	Jan.	--
	1978	--	--	--	--	--	--	--	--	--	--	--	--
>30°N	1966	--	--	--	--	--	--	--	--	--	--	--	--
	1967	--	--	--	--	--	--	--	--	--	--	--	--
	1968	--	--	--	--	--	--	--	--	--	--	--	--
	1969	--	--	--	--	--	--	--	--	--	--	--	--
	1970	--	--	--	--	--	--	--	--	--	--	--	--
	1971	--	--	--	--	--	--	--	--	--	--	--	--
	1972	--	--	--	--	--	--	--	--	--	--	--	--
	1973	--	235	--	--	108	--	--	174°W	--	--	Dec.	--
	1974	--	235	--	--	173	--	--	164°E	--	--	Oct.	--
	1975	--	--	--	--	69	--	--	135°E	--	--	May	--
	1976	179	229	--	131	148	--	170°W	160°W	--	Dec.	Nov.	--
	1977	175	236	--	140	158	--	168°W	163°W	--	Jan.	Jan.	--
	1978	--	--	--	--	--	--	--	--	--	--	--	--

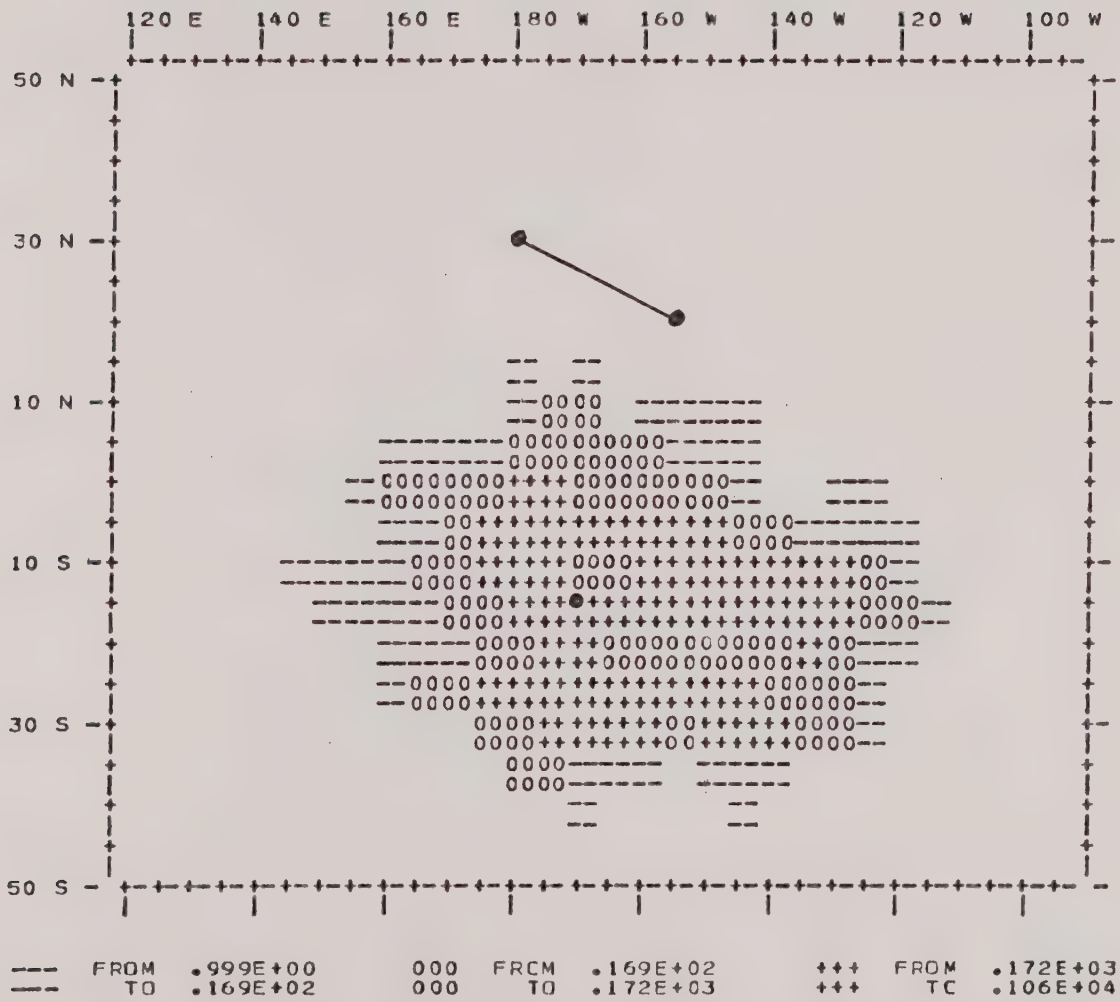


Figure 1.--Distribution of nominal effort (vessel days) by Japanese longliners based in American Samoa during 1965-72, by 5° squares. American Samoa is indicated by a single dot (•), and the Hawaiian Islands by connected dots (•–•). Based on data from Government of American Samoa.

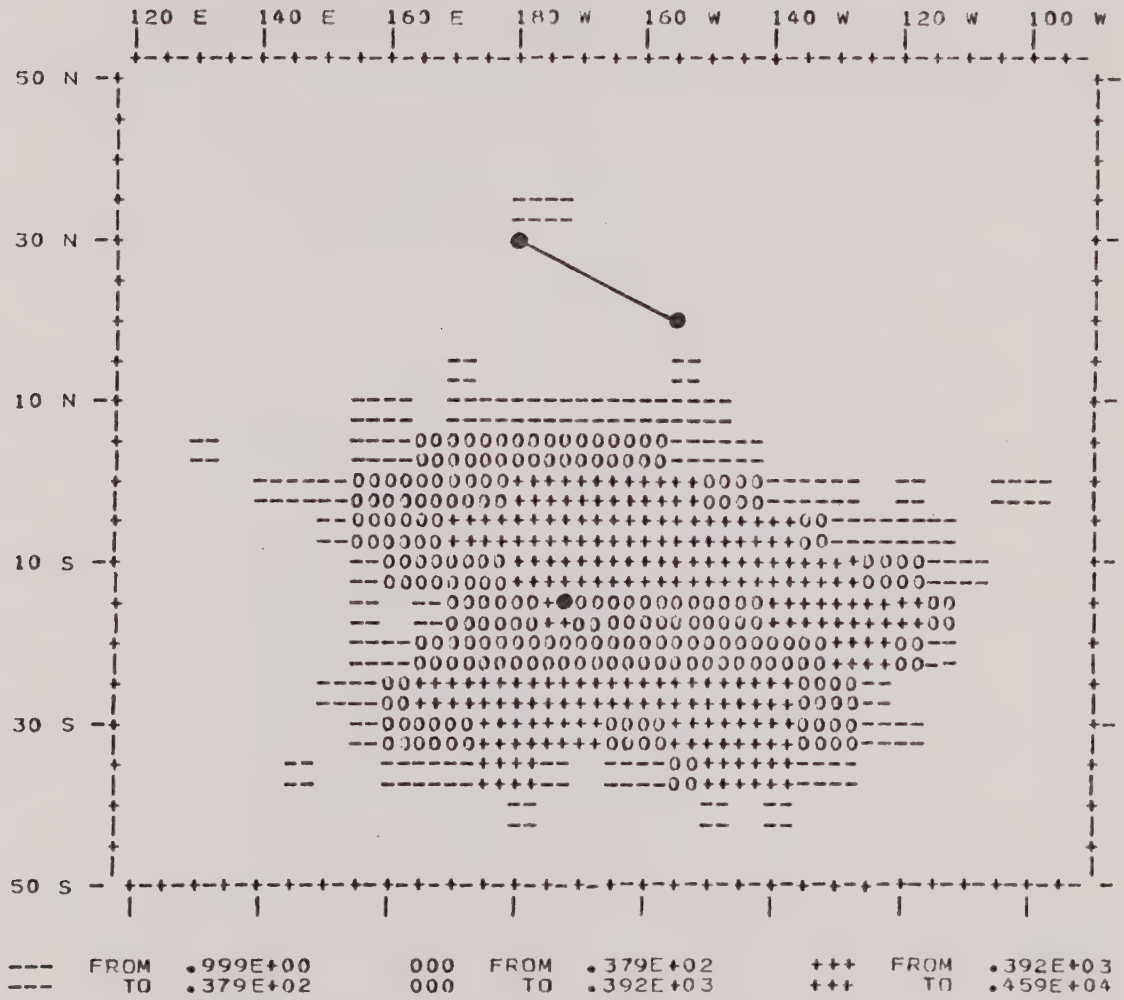


Figure 2.--Distribution of nominal effort (vessel days) by Korean longliners based in American Samoa during 1965-73, by 5° squares. American Samoa is indicated by a single dot (•), and the Hawaiian Islands by connected dots (•—•). Based on data from Government of American Samoa.

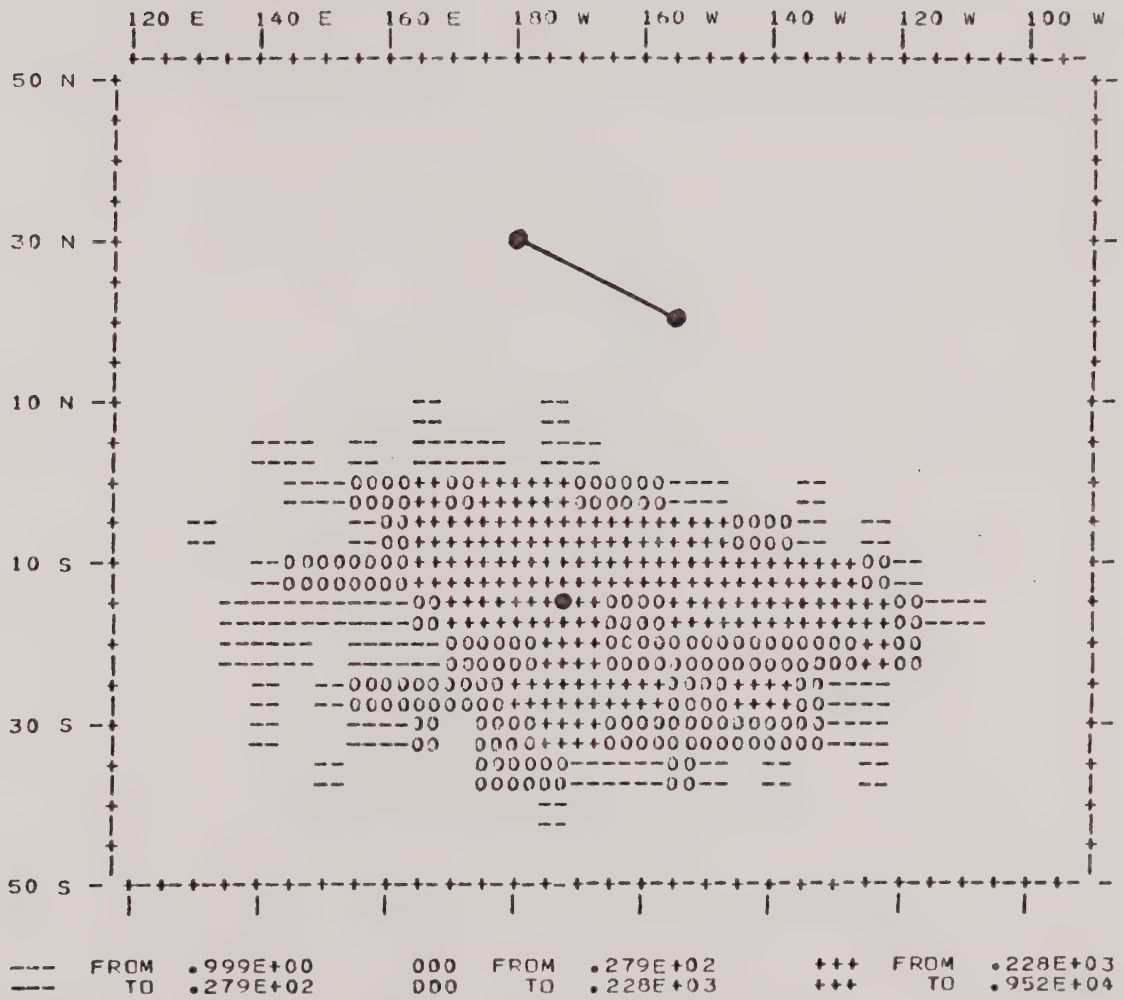


Figure 3.--Distribution of nominal effort (vessel days) by Taiwanese longliners based in American Samoa during 1965-73, by 5° squares. American Samoa is indicated by a single dot (•), and the Hawaiian Islands by connected dots (•—•). Based on data from Government of American Samoa.

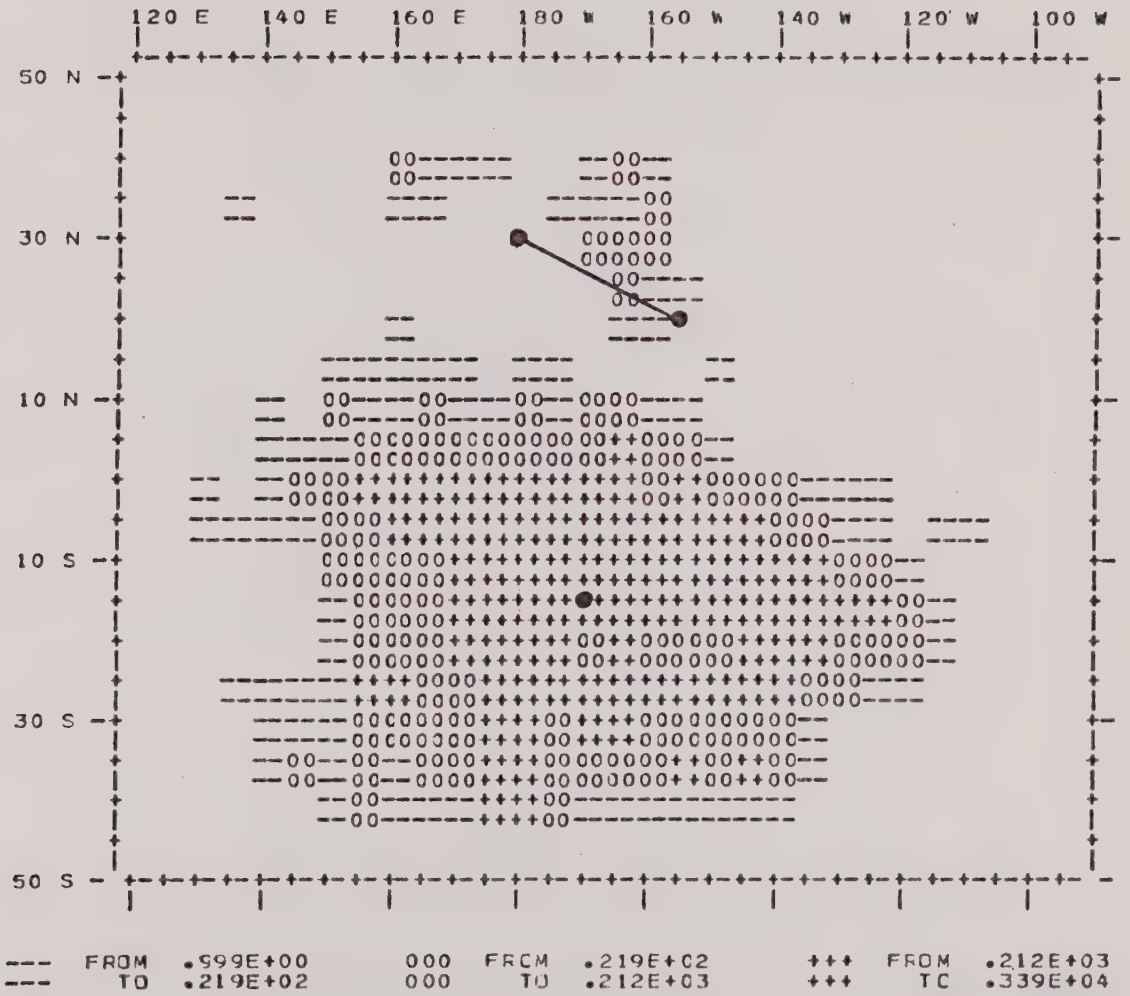


Figure 4.--Distribution of nominal effort (vessel days) by Korean longliners based in American Samoa during 1974-78, by 5° squares. American Samoa is indicated by a single dot (•), and the Hawaiian Islands by connected dots (•—•). Based on data from Government of American Samoa.

Figure 5.--Distribution of nominal effort (vessel days) by Taiwanese longliners based in American Samoa during 1974-78, by 5° squares. American Samoa is indicated by a single dot (•), and the Hawaiian Islands by connected dots (•—•). Based on data from Government of American Samoa.

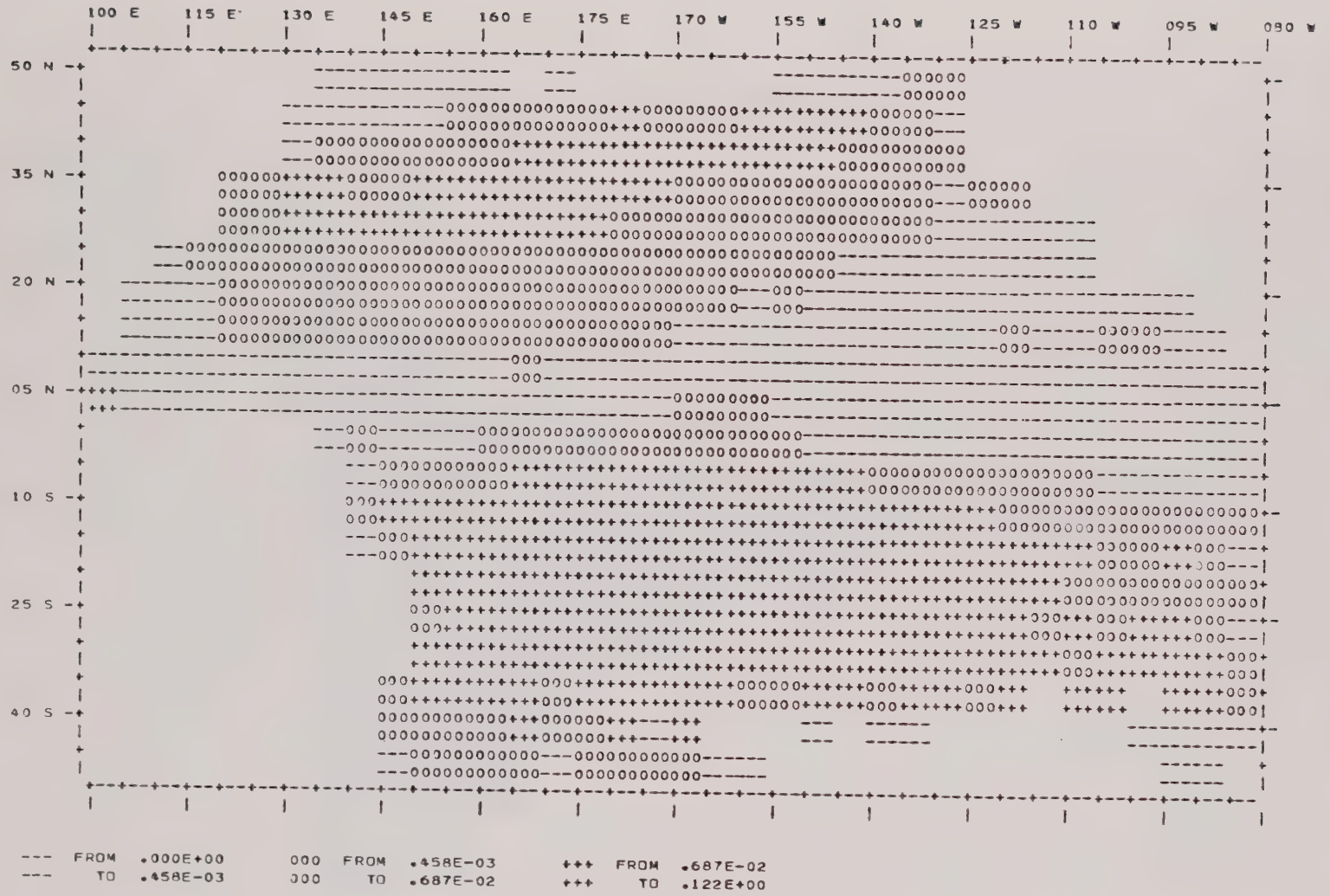


Figure 6.--Distribution of average catch per hook (number of fish) for albacore taken by Japanese longliners in the Pacific, 1952-76. Based on data from Fisheries Agency of Japan.

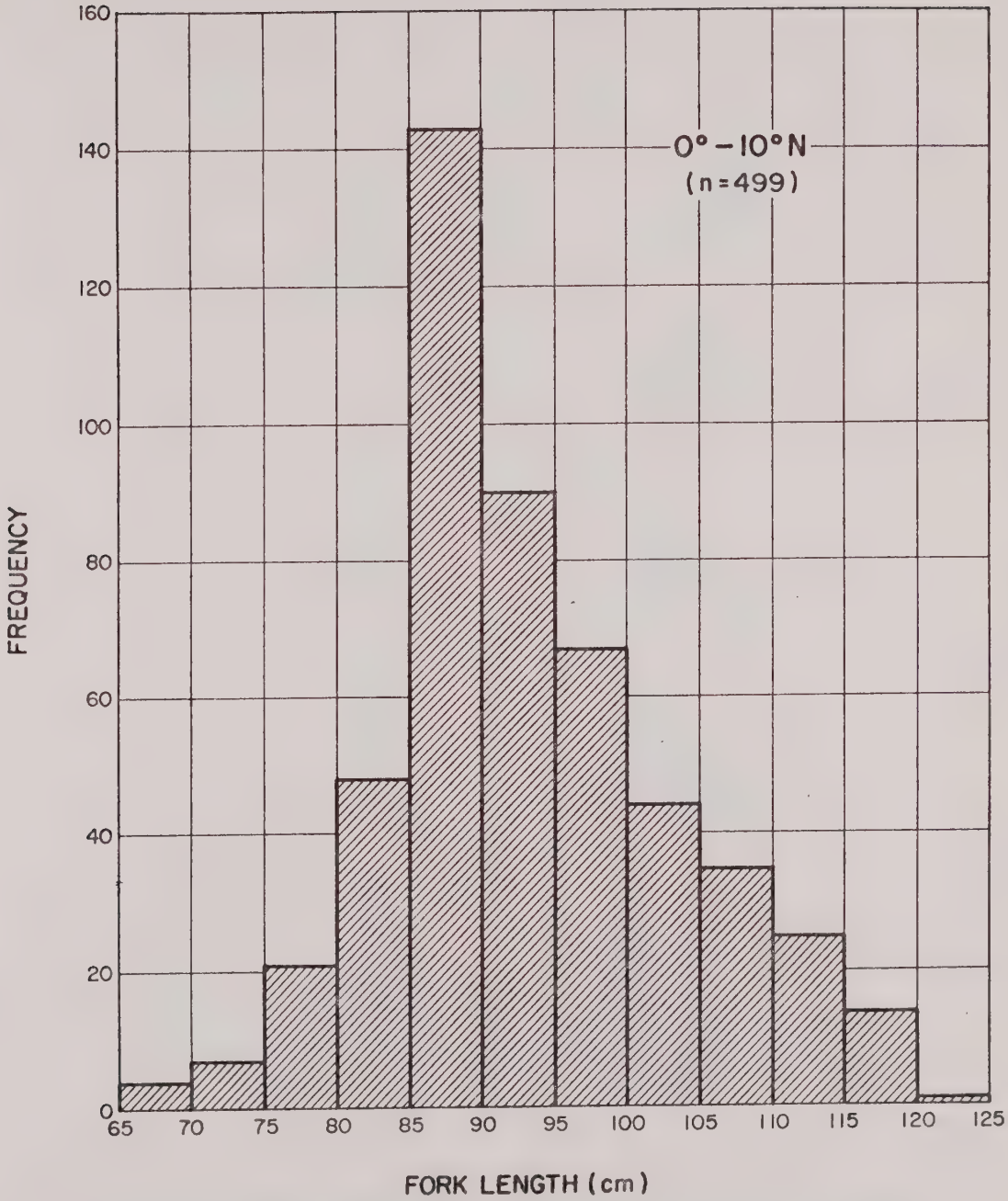


Figure 7.--Distribution of fork length measurements on albacore caught by American Samoa-based longliners, presumably between the equator and lat. 10°N.

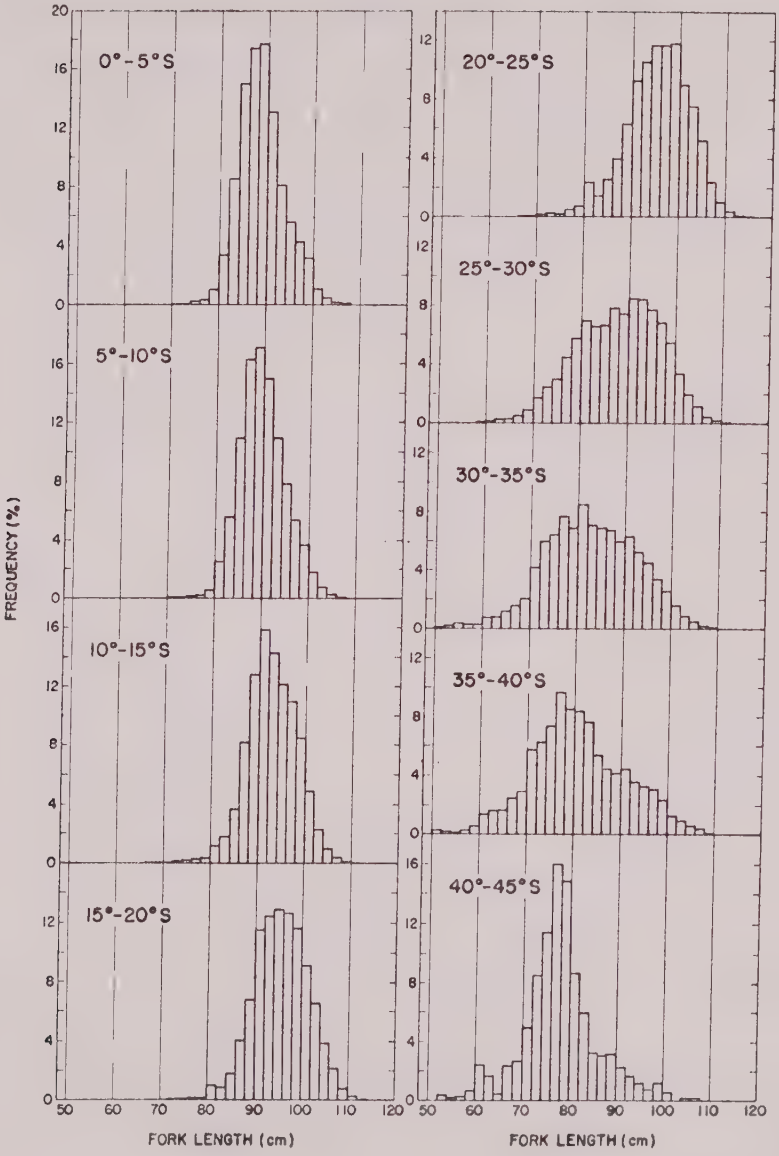


Figure 8.--Fork length composition of South Pacific albacore catches by longline vessels based at Pago Pago, by latitude, 1962-76.

JUL 24 1980

POSSIBLE ENVIRONMENTAL IMPACT OF IMPORTING ANCHOVY INTO HAWAII

Howard O. Yoshida
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service
Honolulu, Hawaii 96812

July 1980

POSSIBLE ENVIRONMENTAL IMPACT OF IMPORTING ANCHOVY INTO HAWAII

The Hawaiian fishery for skipjack tuna, Katsuwonus pelamis, with an average annual ex-vessel value in excess of $2 million, experiences considerable fluctuations in landings from year to year. The annual landings average around 9 million pounds but fluctuate between 5 and 16 million pounds. This fluctuation has several causes, one being the shortage of live bait. Essentially, any small fish will serve as bait and the effectiveness varies from species to species. Hawaiian skipjack tuna fishermen, by far, prefer nehu, Stolephorus purpureus, a small (40-60 mm), fragile anchovy that schools in bays and harbors of the Hawaiian Islands. The seasonal availability of nehu varies greatly, but in general, the supply is insufficient to allow maximum fishing effort by the existing fleet. The problem with the bait supply is particularly serious during the peak skipjack tuna fishing season, from around May to September, when many of the boats spend considerable time obtaining the bait needed to fish skipjack tuna. Obviously, if the boats could fish skipjack tuna instead of spending so much time catching bait, the landings of the Hawaiian fishery would increase proportionately. Furthermore, the nehu are extremely delicate, and do not survive in the baitwells for more than a few days. This factor greatly limits the range of the fishing boats. A solution to the baitfish problem, which would replace time used to catch bait with additional fishing time, could increase the annual catch of skipjack tuna by as much as 66% and provide for an increase in ex-vessel value of the catch of $1.9 million. It should be pointed out

that this increase would occur with the existing fleet; any expansion of fleet size would provide for added incremental growth since available evidence indicates that the skipjack tuna resource is underutilized and could withstand additional fishing pressure.

Various solutions to the baitfish problem have been proposed and researched in the past. The culture of live bait has been tried and found to be either too expensive or the cultured baitfish has been unacceptable to the fishermen. Another approach has been the development of artificial bait, e.g., various types of odor-impregnated food pellets. All of these were found to be ineffective.

One of the most direct and feasible approach to the problem is to bring in a supply of baitfish from areas where they are readily available. In the case of Hawaii, the northern anchovy, Engraulis mordax (Figure 1), from California seems a good possibility. The northern anchovy has been transported to Hawaii in the past on several occasions, mostly on an opportunistic basis and in small quantities. All indications are that this species is hardier than the nehu and would allow the Hawaiian tuna boats to range farther from base port than is now possible with the nehu. Because of the lower mortality to be expected with the northern anchovy, the catch per unit of bait carried to sea should increase substantially. The northern anchovy has been used successfully in fishing for skipjack tuna in the central Pacific. Further, it is one of the principal baitfish used by the tuna bait boats in the eastern Pacific.

The main thrust of our program, then, is to develop the technology needed for the transportation, holding and ancillary requirements to the successful importation of live northern anchovy from California to Hawaii.

Briefly, the activities of this program will be conducted in four phases. Phase 1 will encompass a preliminary review and assessment of various baitfish transport alternatives. Phase 2 will test the feasibility of transporting live bait using the alternative assessed to be most promising. Phase 3 involves the development of a full-scale system of economically transporting bait to Hawaii on a sustaining basis--a system that would supply all of the baitfish needs of the Hawaiian fleet. Phase 4 will comprise report writing.

One of the most serious possible environmental impacts of the program is that the northern anchovy may become established in Hawaiian waters to the detriment of the endemic Hawaiian marine fauna. During the course of various activities of the program northern anchovies will most certainly, whether inadvertently or purposefully, be released in Hawaiian waters. Opportunities to escape will be numerous, e.g., when the anchovies are being held in holding enclosures and when they are being transferred from holding facilities to fishing boats. They will also be deliberately released into the environment when they are chummed as live bait in fishing operations. However, whether or not they will become established in Hawaiian waters as a consequence of the escape of some individuals is difficult to ascertain with any certainty. Knowledge of the biology of the northern anchovy, however, should provide some clues as to the

probability of its establishment in Hawaiian waters, and as to whether its establishment will be detrimental to the Hawaiian fauna.

The northern anchovy is a temperate water species which is found off the coast of North America from the Queen Charlotte Islands, British Columbia to Cape San Lucas, Baja California (Figure 2). They are pelagic schooling fishes and are most common in coastal waters between San Francisco and Magdalena Bay, Baja California. They are ordinarily found in water ranging from 14.6°C (58.2°F) to 20.0°C (68°F) although in the extreme they have been found in water as cool as 5°C (41°F) and as warm as 25°C (77°F). The salinity of the water they occur in range from $<32.5‰$ to $>34.5‰$.

In certain seasons of the year, usually in the summer and fall, large compact schools of northern anchovy are found during the day along submarine escarpments and canyons at depths of 110 m (360 ft) to 183 m (600 ft). During hours of darkness the schools rise to the surface and the anchovies disperse. They start to re-form into compact schools and return to deeper water with the coming of dawn.

Northern anchovies begin to reach sexual maturity at the end of their first year of life when they are about 10.2 cm (4 inches) to 11.4 cm (4.5 inches) long. Almost all anchovies are fully mature when they are 2 years old and are 12.7 cm (5 inches) to 14.0 cm (5.5 inches) long. It is estimated that female anchovies can spawn from 4,025 to 21,297 eggs per spawning. Northern anchovies usually spawn within 60 miles of the coast. However, anchovy eggs have been found as far offshore as 300 miles. The eggs and larvae of anchovies are pelagic.

Northern anchovies spawn throughout the year, particularly in the southern portion of its range. There is a peak in spawning activity in the late winter and spring. Most of the pelagic anchovy eggs have been found in water with temperatures between 13.0°C (55.4°F) and 17.5°C (63.5°F). The threshold temperature for anchovy spawning is believed to be about 11.5°C (52.7°F) or 12.0°C (53.6°F).

The northern anchovy seldom lives over 4 years. They apparently are filter feeders, indiscriminatingly accepting zooplankton or phytoplankton. They have also been found to have small fish in their stomachs. With regard to food, they are direct competitors of the Pacific sardine, Sardinops caeruleus. They also compete with the Pacific sardine for space since both species are found in greatest abundance between Point Conception, California and Magdalena Bay, Baja California. A great number of fishes, birds, and mammals prey on the northern anchovy. Studies have indicated that the northern anchovy is probably the most important forage species in the inshore waters of California and Baja California. Certainly, the northern anchovy is important in the diet of all the large predatory game fish off California.

Whether northern anchovies may become established in Hawaiian waters will depend to a great degree on how successfully they can adapt to the temperature of the water surrounding the Hawaiian Islands. It is believed that one of the primary limiting factors in the distribution of northern anchovy, and indeed most of the species in the genus Engraulis, is water temperature. Generally, fishes in the genus Engraulis have not been found either in the coldest or warmest oceanic conditions. It is

estimated that a range of temperature from 6°C (42.8°F) to 23°C (73.4°F) would include nearly all of its occurrences. We noted that the northern anchovy was usually found in water ranging from 14.6°C (58.2°F) to 20.0°C (68°F). The Hawaiian oceanographic climate, as represented by observations made at Koko Head, Oahu, includes extremes in range of temperature from 22.5°C (72.5°F) in February or March to 27.4°C (81.3°F) in September or October. These observations suggest that the Hawaiian oceanic environment, insofar as temperature is concerned, is not suitable for the northern anchovy. Granted, past experience has shown that live northern anchovy do survive the change in temperature from that found in California waters to that found in Hawaiian waters. But whether they can adapt to these temperatures on a long term and form a viable, reproducing population, i.e., become established, is another matter. Certainly one important factor is the observation on the threshold temperature for anchovy spawning. The water temperature around Hawaii does not get low enough to reach the threshold value required for anchovy spawning.

The salinity values found around Hawaii, again as represented by observations made at Koko Head, Oahu, are within the range the northern anchovy is found in off the west coast of North America. The extremes in salinity observed at Koko Head range from about 34.4‰ in July to 35.5‰ in late fall or early winter. The salinity range is greater in more estuarine conditions. For example, in Kaneohe Bay, Oahu, the annual range in salinity is from 31‰ to 36‰. We noted that northern anchovies were found in waters with salinity ranging from <32.5‰ to >34.5‰. It is believed that the species in the genus Engraulis in general are

not limited by salinity values encountered in the ocean or estuaries. They have been found in water ranging from 2‰ to 39.4‰ in salinity.

To summarize what is known about conditions limiting the distribution of the northern anchovy to this point, it has been indicated that salinity is not limiting but temperature most likely is. However, it has also been shown that there are vast areas of ocean habitats with suitable temperature that do not support Engraulis populations. This suggests that there are other factors besides salinity and temperature that are important to Engraulis, including the northern anchovy. Because Engraulis is a coastal genus, i.e., although their eggs and larvae are sometimes found far offshore, they are definitely tied to a coastal population; some scientists believe that coasts are essential to Engraulis. If this observation is correct, then the lack of an extensive coastline in Hawaii will be a negative factor in the possible establishment of the northern anchovy in Hawaiian waters.

Evidence supporting the observation that Hawaii's oceanographic environment may not be conducive to the establishment of the northern anchovy may be found in past experiences with this species. In 1932, a release of 6,000 northern anchovy was made in Kaneohe Bay, Oahu. The anchovies were part of a load of live bait transported from California to Hawaii by a California tuna clipper. These anchovies did not survive and no reproducing population was established from this introduction. Although not well documented, there have been other inadvertent or purposeful releases of northern anchovies in Hawaiian waters, but, this species has not become established from these releases.

It should be pointed out that the number of individuals introduced may be crucial in determining the success of the establishment

of a species, especially in a marine environment. The experience in the establishment of the Marquesan sardine, Sardinella marquesensis, in Hawaii indicated that those releases with 20,000 or more individuals were important in their establishment while those of 10,000 or less were not. Our program of importing northern anchovy will not be with the idea of trying to establish them in Hawaii. Numbers of northern anchovy will surely escape confinement. They would also be successful, to some unknown degree, in escaping their predators after being chummed as bait. However, the numbers surviving such accidental or purposeful releases should be minimal and certainly not in quantities favorable to their establishment.

Up to this point we have discussed the factors that would or would not be conducive to the establishment of northern anchovy in Hawaii. We can conclude from the evidence that the chances are virtually nil that northern anchovy can become established as a consequence of our program. However, the possibility exists, howsoever small, that they may become established. What would then be the consequences of the establishment of northern anchovy in Hawaiian waters? The most undesirable consequence would be that they would compete with native Hawaiian species for food and space to the detriment of the native fishes. Some of the species that the northern anchovy may possibly compete with are the nehu, the akule or bigeye scad, Trachurops crumenophthalmus and the opelu or mackerel scad, Decapterus pinnulatus.

The nehu, akule, and opelu appear to be primarily zooplankton feeders (Tables 1 and 2). Although food studies on the northern anchovy are not plentiful, it appears that the northern anchovy is slightly

lower on the trophic scale than nehu, akule, and opelu. We noted that they indiscriminately fed on zooplankton and also phytoplankton. While studies on this subject is lacking, akule and opelu probably exercise some selection in their feeding. There is some evidence to indicate that the nehu prefers the crustacean components of the zooplankton, at least in some areas of their habitat. Thus, although the northern anchovy may compete somewhat with nehu, akule, and opelu for food in that part of its diet that includes zooplankton, it does not directly compete in the sense that it is not a selective feeder.

The northern anchovy will no doubt compete for space with opelu and akule if they become established in Hawaiian waters. It is difficult to assess the consequences of this type of competition. Off the coast of California, however, the Pacific sardine is considered the chief competitor of the northern anchovy. Discounting the effects of the fishery on the Pacific sardine, there is no clear evidence that the Pacific sardine has not been able to compete successfully with the northern anchovy for space and food. Other similar species off the California coast apparently compete with the northern anchovy and with each other presumably without any deleterious effects. There is no reason to believe that the akule and the opelu will not be able to compete successfully with the northern anchovy in the Hawaiian environment.

The northern anchovy will probably not compete with the nehu for space. Ecologically, the nehu is restricted more to sheltered coastal waters and estuaries whereas the northern anchovy is more pelagic. The nehu spawns in sheltered bays and harbors whereas the eggs and larvae of the northern anchovies are pelagic.

Other possible environmental impacts of the program are the possibility of the transfer of disease with the northern anchovy and the inadvertent introduction of other species of fish together in the shipments of northern anchovy. Very little is known about diseases in populations of pelagic marine fishes. However, as a precautionary measure all shipments of northern anchovy will be treated with appropriate chemicals (e.g., copper sulfate) to reduce the possibility of the introduction of diseases. Furthermore, specimens from trial shipments will be subjected to critical examination by a fish pathologist to insure that the anchovies are disease free. The chances that other species of fish will be mixed with the shipment are considered to be small. However, even if small numbers are mixed with the northern anchovies, the chances that these temperate water species will survive and become established are even less than for the anchovy for reasons already elaborated.

Although we have so far discussed only the unwelcome consequences of the establishment of the northern anchovy in Hawaii there may be some beneficial results. It was noted that the northern anchovy was an important item in the diet of all the large predators in the inshore waters off California. In the forage poor waters of Hawaii the northern anchovy may be a welcome addition to the diet of Hawaiian predator fishes. Indeed, they may act to attract larger numbers of commercially important fishes like the tunas and billfishes to Hawaiian waters. It has been noted in California that the number of Pacific bonito, Sarda chiliensis, taken by California party boats has increased greatly concurrent with the growth of the northern anchovy population. More obviously, the establishment

of the northern anchovy may be another source of live bait for the Hawaiian skipjack tuna fishermen and may form the basis of a new fishery for bait similar to the California bait fishery.

In summary, we have indicated several conditions that make the chances of the establishment of the northern anchovy in Hawaiian waters highly unlikely: the lack of suitable temperatures in general; and more important, the lack of suitable temperatures to trigger anchovy spawning; and finally the possible importance of extensive coastlines, which Hawaii lacks to support an anchovy population. We have also pointed out that the establishment of an anchovy population in Hawaiian waters will probably not have a deleterious effect with regard to the Hawaiian fauna. Finally, we have suggested possible benefits of the establishment of an anchovy population in that it will provide much needed forage for Hawaiian predator species, provide bait for the Hawaiian skipjack tuna fishermen, and may also form the basis of another fishery.

REFERENCES

Baxter, J. L.

1967. Summary of biological information on the northern anchovy, Engraulis mordax Girard. Calif. Coop. Oceanic Fish. Invest. Rep. 11:110-116.

Brock, V. E.

1960. The introduction of aquatic animals into Hawaiian waters. Int. Rev. Gesamten Hydrobiol. 45:463-480.

Frey, H. W. (editor).

1971. Pelagic wetfish. Northern anchovy. In California's living marine resources and their utilization, p. 48-51. Calif. Dep. Fish Game, Resour. Agency.

Hiatt, R. W.

1951. Food and feeding habits of the nehu, Stolephorus purpureus Fowler. Pac. Sci. 5(4):347-358.

Kawamoto, P. Y.

1973. Management investigation of the akule or bigeye scad, Trachurops crumenophthalmus (Bloch). Completion report prepared for National Marine Fisheries Service under Commercial Fisheries Research and Development Act, P.L. 88-309, Project No. H-4-R. Hawaii Dep. Land Nat. Resour., Div. Fish Game, 28 p. (Mimeogr.)

Reid, J. L., Jr.

1967. Oceanic environments of the genus Engraulis around the world. Calif. Coop. Oceanic Fish. Invest. Rep. 11:29-33.

Seckel, G. R.

1972. Hawaiian-caught skipjack tuna and their physical environment. Fish. Bull., U.S. 70:763-787.

Yamaguchi, Y.

1953. The fishery and the biology of the Hawaiian opelu, Decapterus pinnulatus (Eydoux and Souleyet). M.S. Thesis, Univ. Hawaii, 126 p.

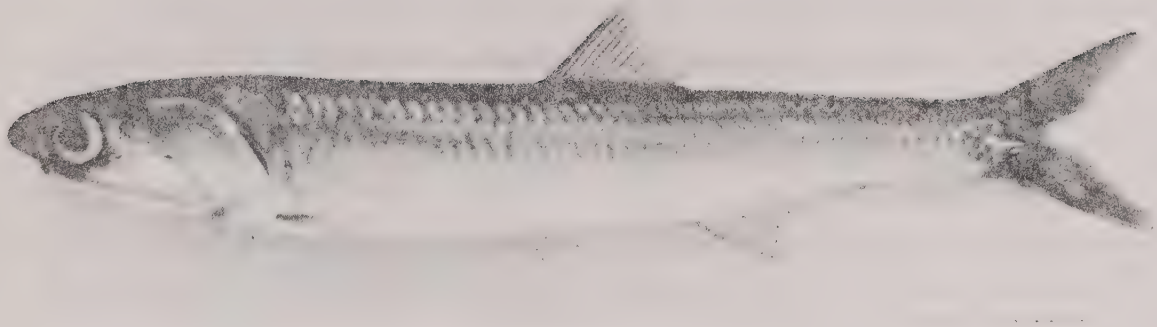


Figure 1.--Northern anchovy, Engraulis mordax. (From Frey 1971.)

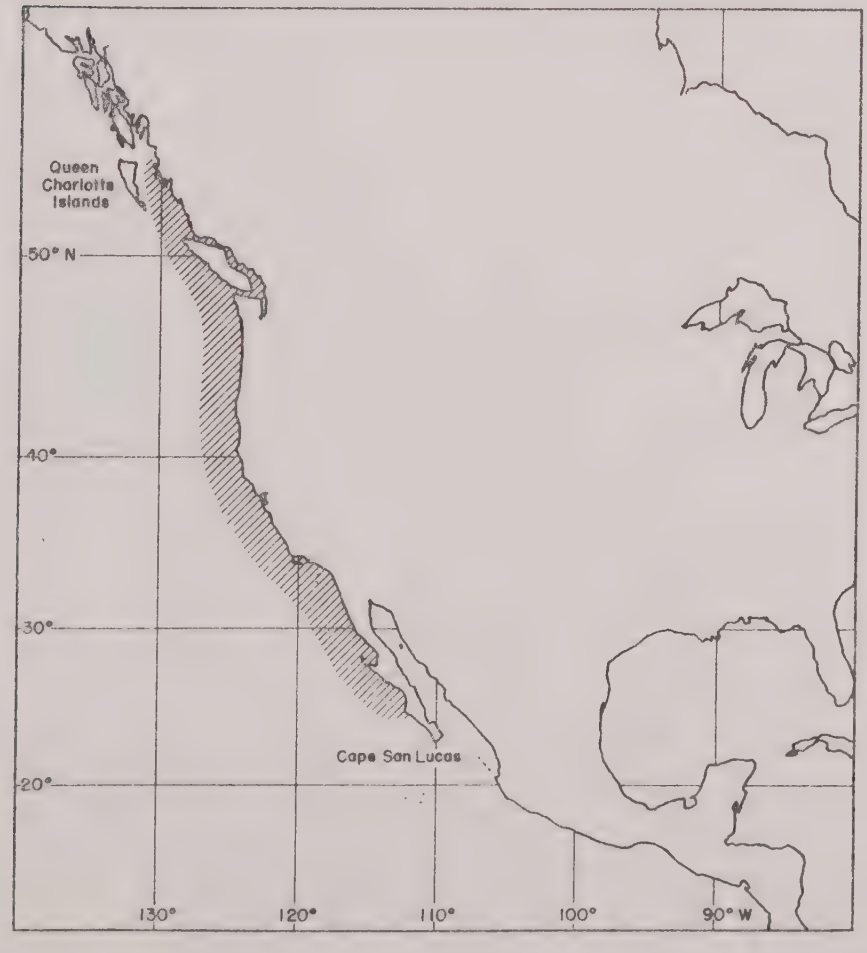


Figure 2.--The distribution of northern anchovy, Engraulis mordax, off the coast of North America. (Adapted from Reid 1967.)

Table 1.--Food of nehu, *Stolephorus purpureus*, in Kaneohe Bay, Oahu, based on an analysis of 80 stomachs. (From Hiatt 1951:Table 2.)

Organism	Percentage frequency of occurrence among fish examined	Average number taken per fish containing the item	Percentage composition of food items based on total number of organisms found in the stomachs
Copepods			
Adults	79	16	35
Eggs	30	23	19
Shrimps			
Adults	6	1	Trace
Mysis	29	19	15
Zoeae	5	11	1
Barnacle larvae			
Nauplii	25	20	13
Cypris	25	7	5
Crab zoeae	25	12	8
Amphipods (Hyperiidae)	11	7	2
Ghost shrimps, *Leucifer faxonii*	11	2	1
Isopods	4	2	Trace
Gastropod veliger larvae	1	1	Trace
Ostracods	1	2	Trace
Stomatopod larvae	1	8	Trace
Fish larvae	1	3	Trace
Diatoms	3	4	Trace

Table 2.--Food of opelu. Stomach analyses of 24 opelu taken off Brown's Camp, Oahu, May 3, 1951. (From Yamaguchi 1953:Table 7.)

No.	Length cm	Sex	Copepod	Amphipod (Hyperiidae)	Euphausiidae	Ghost shrimp (Leucifer)	Shrimp	Crustacean larvae	Crab megalopa	Pelecypod mollusc larvae	Stomatopod larvae	Chaetognatha (Sagitta)	Fish larvae	Fish scales
1	26.0	M	2	18					8	1			1	
2	23.5	F		12		4	2	7	14					
3	22.5	M	13	14	5			6	2	2	2	3		x
4	21.6	M		6	2		3	2	10	2			3	
5	21.5	M		26		6		10	11			2	1	
6	23.0	F	5	4	4	3	1		3	3				
7	25.2	F	3	10				3	2	1	1	1		x
8	23.4	M	3	16					12			4		
9	24.1	M		5	6	2	3	2	3				1	
10	25.0	F	10	16	3	1	2		8	1			2	
11	21.8	M		20			5	12	17	2		2	1	x
12	23.0	M	2	12	1	5	6		10		4		1	x
13	26.8	F	13	22		5	2		3		1			
14	21.0	M		8	2	2	3		21	2	2			
15	22.4	F		2		1	1	6	4		1		2	
16	23.6	M	9	10				6	4	1		4		x
17	21.5	M		8	3		4		3		3	1	3	
18	21.8	M	4		3	1	7	4	11	3	2	2		
19	23.7	M	16	16		2	4		13			1	1	
20	21.9	F	2	29	5	2	2		2					
21	24.0	M	2	5	3		2	7	5		1			
22	23.3	F		6		8	5		22	1		1	1	x
23	22.5	M		18		2	2	12	12		3	3	2	
24	21.8	M	18	7	2	3			10			1	1	
			102	290	39	47	54	77	210	19	20	25	23	

COMMERCIAL BOTTOM HANDLINE FISHERY IN THE NORTHWESTERN HAWAIIAN ISLANDS, 1959-77

Jeffrey J. Polovina and Robert B. Moffitt
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

AUG 13 1980

August 1980

COMMERCIAL BOTTOM HANDLINE FISHERY IN THE NORTHWESTERN HAWAIIAN ISLANDS, 1959-77

Commercial bottom fishing has been pursued on a small scale in the Northwestern Hawaiian Islands (NWHI) at least since 1945. This report displays and analyzes the bottom fish catch and effort data collected by the Hawaii Division of Fish and Game (HDFG) during the period 1959-77.

The data collected by HDFG consist of catch reports filed by fishermen. The report form requests the fisherman's name, boat number, license number, daily report of the area fished, gear used, weight, number, and the wholesale value of the catch by species. Examination of the catch reports for bottom fishing in the NWHI indicates that fishermen usually did not report catches on a daily basis, but rather, on a boat trip basis. In addition, the number of fish and location fished generally were not precisely reported. Thus, the basic data on the commercial bottom handline fishery in the NWHI consist of the weight and wholesale value by species of fish caught by boat trip. Data collected since 1959 are stored on a computer tape.

THE FISHERY

The basic gear used commercially is the bottom handline. Occasionally, bottom fish will be caught by commercial vessels with a fish trap, but records indicate that trap catches constitute an insignificant portion of the total catch during 1959-77. All subsequent catch data will refer only to catches with bottom handline.

There are essentially 10 species which make up the commercially important bottom fish from the NWHI (Table 1). Of these 10, the bulk of the catch consists of 4 species--ulua, Caranx spp. and Carangoides spp.; hapu'upu'u, Epinephelus quernus; kahala, Seriola dumerili; and opakapaka, Pristipomoides filamentosus.

During the period 1959-77, over 50 metric tons of bottom fish were reported caught in the NWHI on handline gear. One vessel accounted for 95.5% of this catch.

CATCH AND EFFORT

The annual number of boat trips devoted to bottom fishing in the NWHI varied during the period 1959-77 from a high of 20 trips in 1973 and 1977, to a low of 4 trips in 1969. The general trend of effort consists of an average of approximately 14 trips per year during 1959-64, a decline to a minimum of 4 trips in 1969, and an increase to an average of approximately 17 trips per year during 1971-77 (Figure 1 and Table 2).

The trend in total weight caught has paralleled the trend in effort with a dip during the period 1965-69 (Figure 2). There has also been a general decline in total weight caught and a change in the species

composition by trip. A plot of annual catch by species indicates that from 1959 to 1965, an average of approximately 18,000 kg of ulua was caught annually. Since 1965 the catch of ulua has declined and has been replaced by hapu'upu'u as the most abundant species (by weight) in the trip catch (Figure 3 and Table 3).

The reasons for both the "U"-shaped effort curve and the change in composition of annual catch may be due to economic factors rather than biological. An examination of the trend in wholesale prices indicates that prices basically remained constant from 1959 to 1969 (Figure 4 and Table 4). Since fuel and other costs rose during that period, the profitability from bottom fishing in the NWHI decreased. Effort during the period 1965-69 reflected the decreased profitability. Since 1969, wholesale prices increased and as a result, effort increased.

Although the total landings of bottom fish has declined, the total value especially since 1969, has increased (Figure 5 and Table 2).

An examination of effort by month for all fishing trips during 1969-77 does not indicate a strong preference for any season (Table 5).

SUSTAINABLE YIELD

Fishermen reporting bottom fish catches from the NWHI do not precisely report the location fished. The locations reported on the HDFG forms for bottom fish can only be used reliably to establish that the fishing occurred in the NWHI. Since we cannot, therefore, determine catch and effort by bank or region, it is not appropriate to estimate sustainable yield directly with production analysis.

We do, however, have results of production analysis for bottom fish stocks around the main Hawaiian Islands. A range of annual maximum sustainable yield (MSY) for all commercial species of bottom fish per nautical mile of 100-fathom contour has been estimated from 105 kg/nmi for the Oahu bank to 272 kg/nmi for the Maui, Molokai, and Lanai bank (Ralston and Polovina[1]). The total length of the 100-fathom contour lines from all the banks in the NWHI is 1,060 nmi. If we assume that abundance and population dynamics in the NWHI are comparable per length of 100-fathom contour to the main Hawaiian Islands, then an estimated range of annual MSY for the entire NWHI for biomass of all commercial species ranges from 111,300 kg based on the Oahu value to 288,320 kg based on the value from the Maui, Molokai, and Lanai bank. Since the total reported bottom fish catch from the NWHI in 1977 was 35,576 kg, this result suggests that the region has potential for much greater exploitation.

---

[1]Ralston, S., and J. Polovina. A multispecies stock production model for Hawaii's handline fishery. Manuscr. in prep. Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, P. O. Box 3830, Honolulu, Hawaii 96812.

Table 1.--Commercially important species of bottom fish in the Northwestern Hawaiian Islands.

Scientific name	Commonly used name
Lutjanidae	
Pristipomoides filamentosus	Opakapaka
P. sieboldii	Kalikali
P. zonatus	Gindai
Etelis carbunculus	Onaga
E. marshi	Ehu
Aprion virescens	Uku
Serranidae	
Epinephelus quernus	Hapu'upu'u
Carangidae	
Seriola dumerili	Kahala
Caranx spp. and *Carangoides* spp.	Ulua
Mullidae	
Mulloidichthys vanicolensis	Weke-ula

Table 2.--Total value and weight of catch and number of trips for bottom handline fishery in the Northwestern Hawaiian Islands.

Year	Dollar value	Kilograms caught	No. of trips
1959	26,896	32,164	10
1960	45,779	49,515	16
1961	30,115	34,476	11
1962	25,363	29,244	13
1963	32,653	40,730	18
1964	39,277	47,260	19
1965	20,118	25,154	9
1966	18,213	21,935	9
1967	13,775	14,822	6
1968	14,320	15,172	6
1969	14,812	18,113	4
1970	39,147	33,683	11
1971	50,206	34,180	17
1972	41,992	19,356	17
1973	62,759	28,050	20
1974	48,899	22,313	15
1975	63,873	27,012	14
1976	78,476	26,730	14
1977	95,659	35,576	20

Table 3.--Total catch of handline for selected bottom fishes in the Northwestern Hawaiian Islands in kilograms.

Year	Opakapaka	Kahala	Hapu'upu'u	Ulua	Kalikali	Onaga	Ehu	Uku	Gindai	Weke-ula
1959	11,796	4,677	7,500	7,865	110	--	95	60	36	--
1960	12,828	3,013	6,340	23,055	166	3,497	461	22	131	--
1961	10,255	6,311	1,340	16,092	32	128	205	50	46	17
1962	8,645	2,203	4,715	12,950	155	105	316	5	102	3
1963	5,320	5,444	9,024	18,305	186	315	1,265	685	125	61
1964	5,336	4,456	6,715	25,054	100	4,444	1,088	17	50	--
1965	1,002	2,464	4,959	14,872	15	386	1,023	431	2	--
1966	2,130	3,089	9,010	7,413	8	46	111	122	3	3
1967	1,452	994	6,474	5,620	18	1	200	40	22	--
1968	413	1,378	4,476	8,335	12	11	410	84	53	--
1969	395	614	1,321	15,681	9	--	54	18	20	--
1970	1,444	5,821	12,192	11,016	347	135	1,511	833	376	7
1971	2,745	2,356	15,829	10,165	185	320	1,927	134	515	4
1972	349	2,200	8,146	1,102	403	492	4,494	1,886	274	10
1973	585	3,642	16,780	994	632	1,300	2,596	1,060	456	5
1974	1,688	1,073	9,348	4,052	432	747	2,631	2,138	183	22
1975	6,274	1,730	9,849	7,920	175	80	828	104	35	19
1976	4,695	2,112	13,716	4,255	22	493	875	554	--	8
1977	9,812	5,630	10,262	7,360	38	16	564	1,820	52	20

Table 4.--Wholesale price per kilogram for some bottom fishes.

Year	Opakapaka	Kalikali	Onaga	Uku	Gindai	Hapu'upu'u	Kahala	Ulua
1959	$0.92	$0.86	--	$0.99	$0.68	$0.97	$0.44	$0.79
1960	1.08	0.95	$1.41	0.99	0.90	1.06	0.48	0.79
1961	0.90	0.97	1.32	0.99	0.68	1.14	0.53	0.77
1962	0.97	0.79	1.25	0.73	0.64	0.92	0.57	0.81
1963	1.06	0.81	1.61	0.92	0.79	0.84	0.53	0.73
1964	1.08	0.90	1.39	0.95	0.79	0.84	0.51	0.73
1965	1.21	0.84	1.50	1.14	1.10	0.95	0.51	0.70
1966	1.12	1.01	2.11	1.03	0.88	0.99	0.51	0.66
1967	1.34	0.68	3.30	1.19	0.66	1.01	0.64	0.77
1968	1.50	2.55	3.12	2.44	1.36	1.30	0.59	0.73
1969	1.94	2.07	--	1.32	1.85	1.50	0.42	0.75
1970	2.29	2.55	2.75	1.47	1.72	1.36	0.59	0.79
1971	1.98	2.38	3.32	1.74	1.65	1.63	0.81	0.92
1972	3.39	2.44	3.72	1.69	2.02	2.09	1.06	1.74
1973	2.16	2.31	3.52	1.98	2.07	2.27	1.28	1.74
1974	2.44	2.73	4.47	2.29	2.07	2.22	0.86	1.30
1975	3.34	2.22	2.95	1.85	2.16	2.44	1.14	1.69
1976	3.78	3.39	3.89	3.50	--	2.93	1.39	2.53
1977	3.78	1.78	5.65	3.72	2.84	2.86	1.36	2.40

Table 5.--Total boat trips per month in the Northwestern Hawaiian Islands, 1959-77.

Month	No. of trips
January	10
February	17
March	17
April	22
May	26
June	20
July	22
August	19
September	30
October	21
November	21
December	24

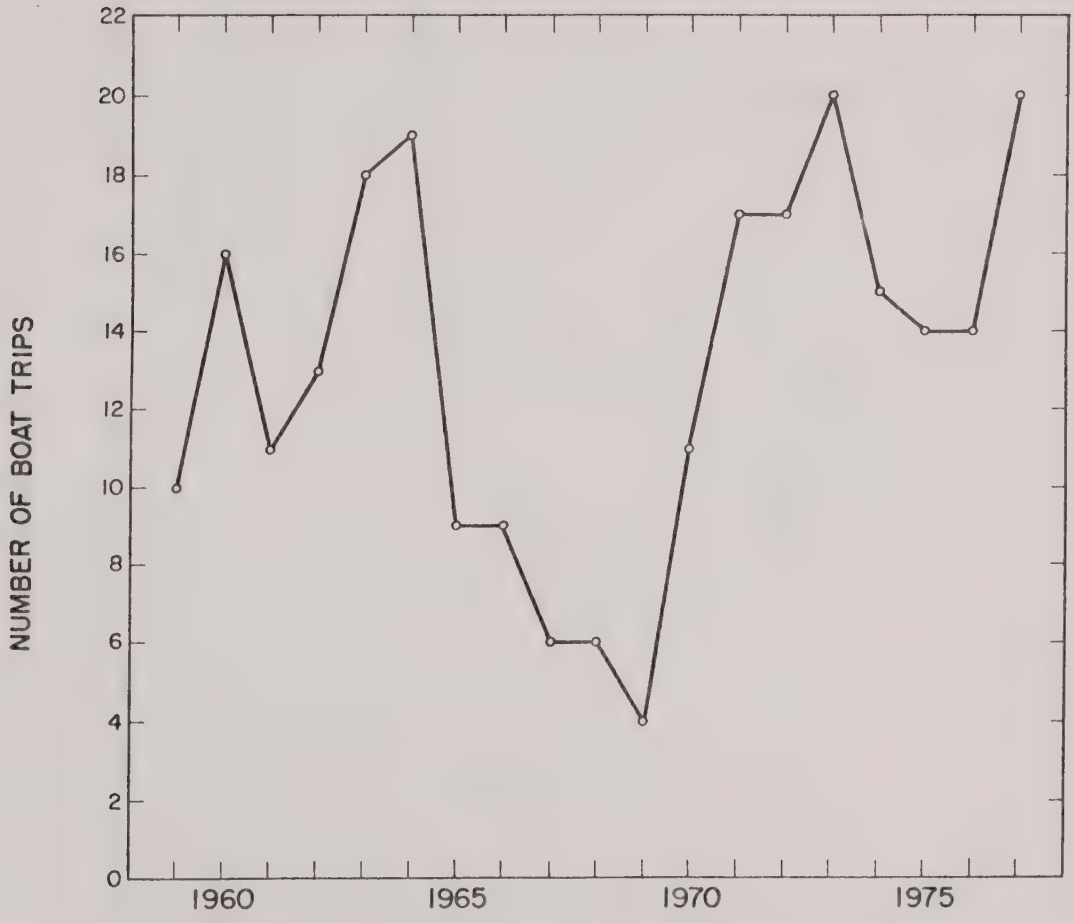


Figure 1.--Total effort in boat trips to the Northwestern Hawaiian Islands for bottom handline fishery.

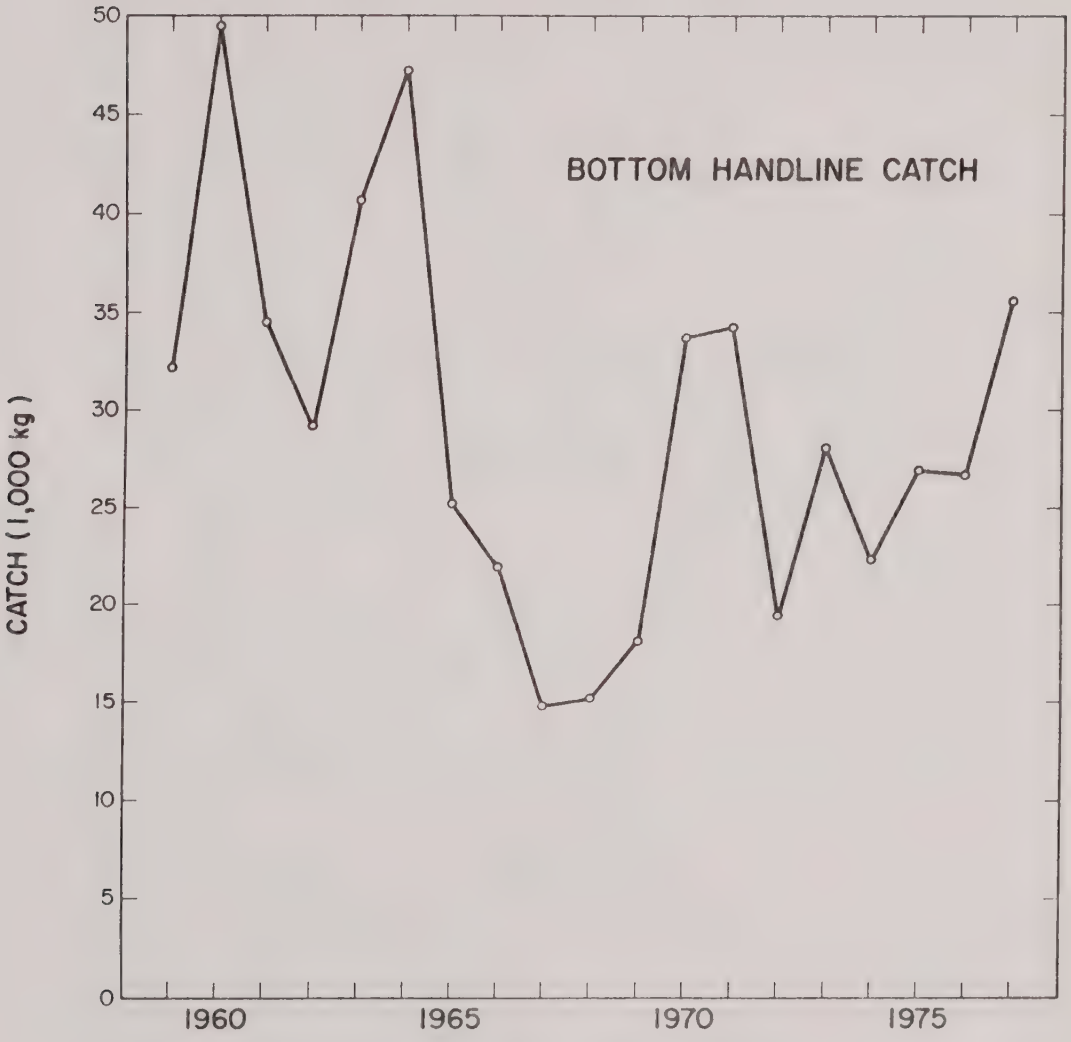


Figure 2.--Total bottom handline catch in kilograms from the Northwestern Hawaiian Islands.

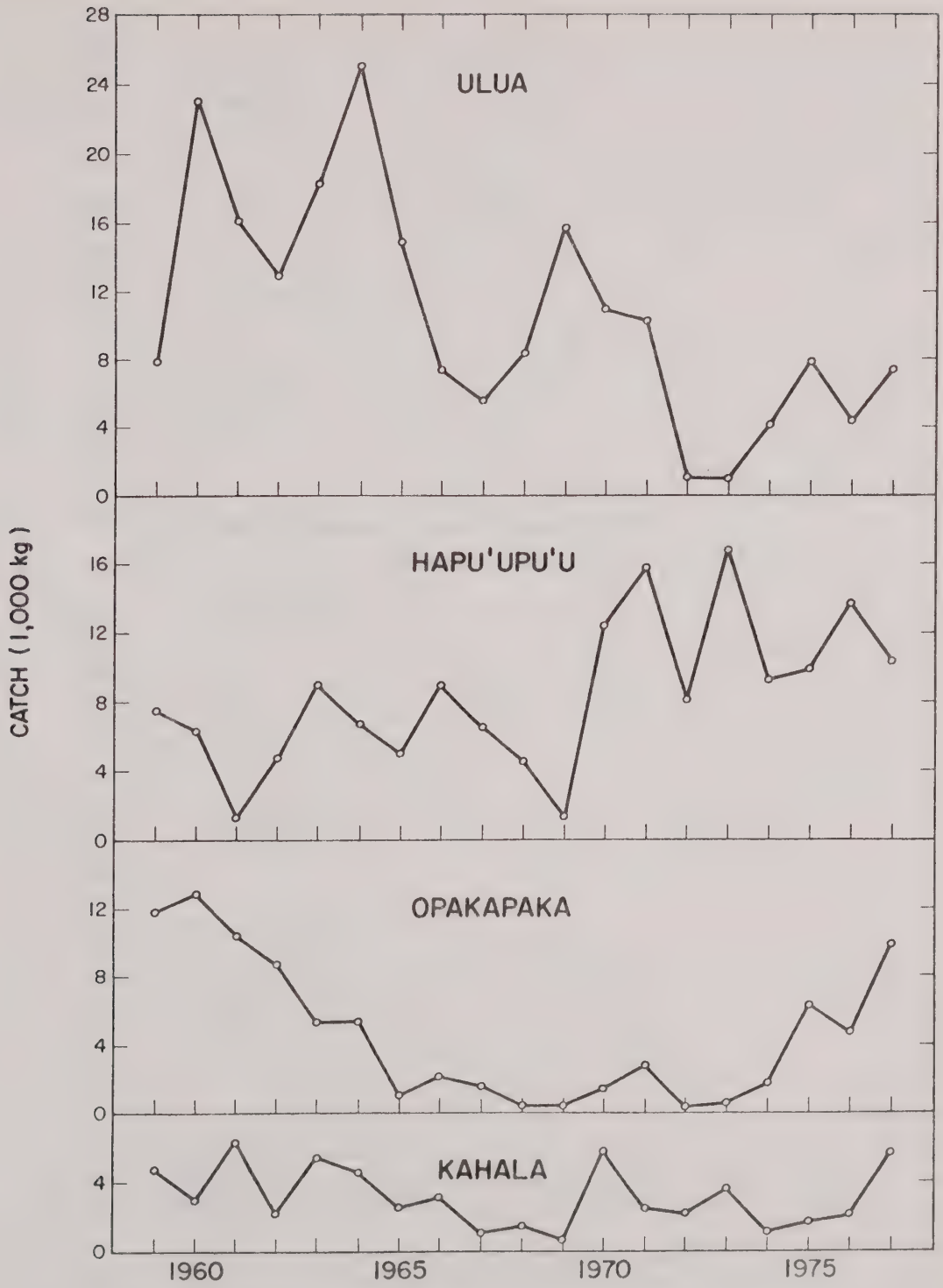


Figure 3.--Annual catches of ulua, kahala, hapu'upu'u, and opakapaka with bottom handline from the Northwestern Hawaiian Islands.

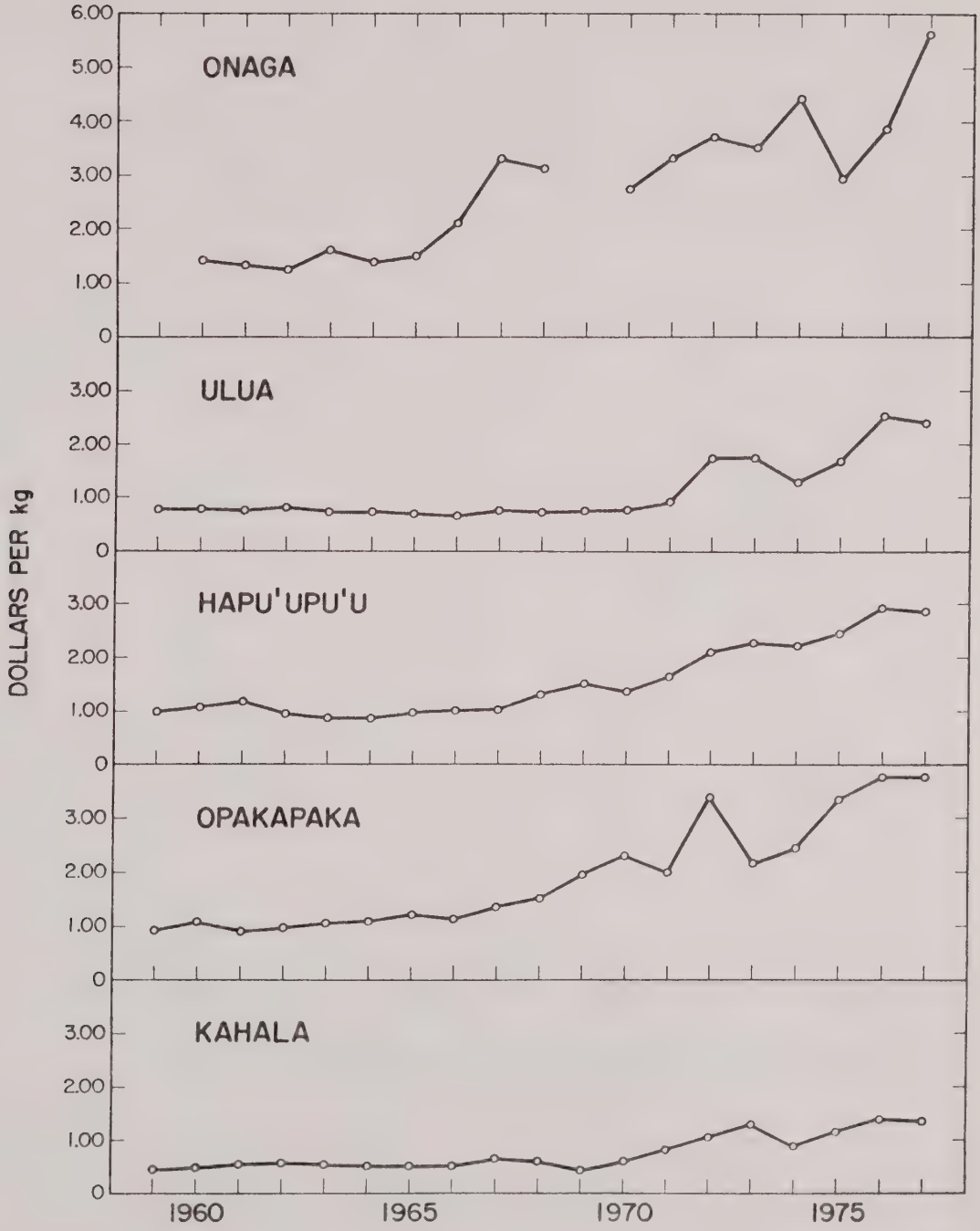


Figure 4.--Wholesale price per kilogram for species of bottom fish from the Northwestern Hawaiian Islands.

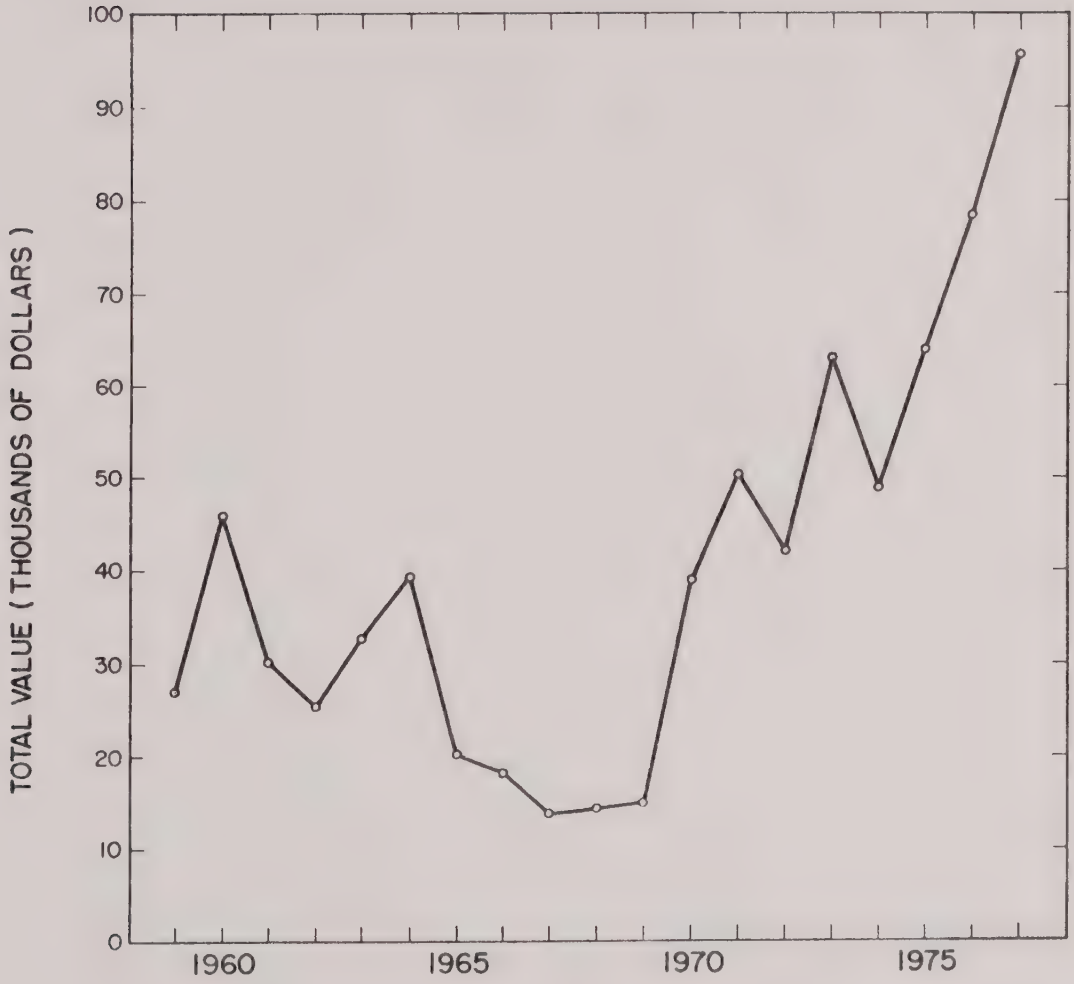


Figure 5.--Value of all bottom handline catches from the Northwestern Hawaiian Islands.

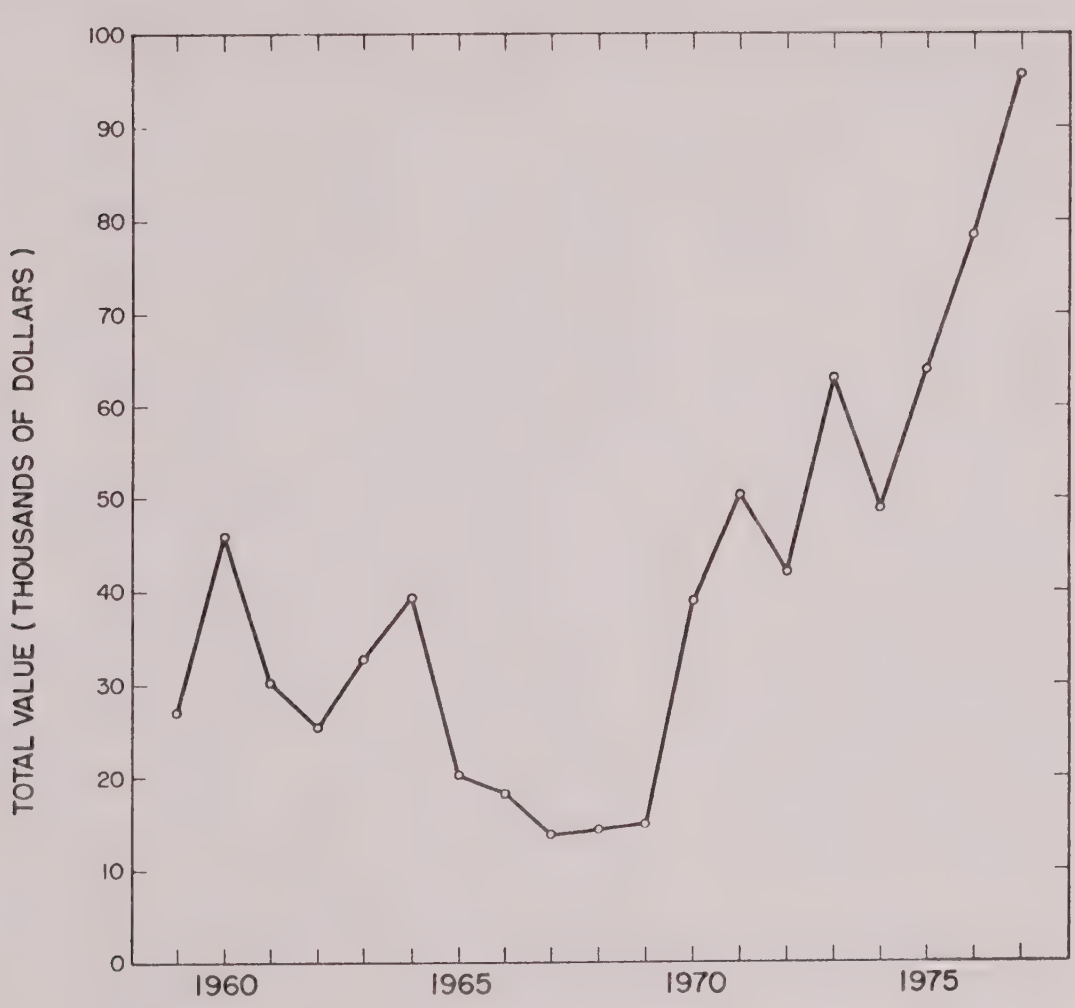


Figure 5.--Value of all bottom handline catches from the Northwestern Hawaiian Islands.

September 1980
Southwest Fisheries Center Administrative Report H-80-12

A STUDY OF LIVE AND DEAD BILLFISHES CAUGHT ON LONGLINE GEAR

By

Heeny S. H. Yuen

Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

INTRODUCTION

The Fishery Conservation and Management Act of 1976 (FCMA) declared a Fishery Conservation Zone (FCZ) within which all fisheries except for highly migratory species of tunas are to be managed. The FCMA mandates the regulation of foreign fishing activity within the FCZ, a band of 200 nautical miles bordering all coasts of the U.S. and its possessions, through the vehicle of Fishery Management Plans (FMP). Fishing for highly migratory tunas, however, is exempt from regulatory measures authorized by the FCMA.

A common method, perhaps the most common method of foreign fishermen, of fishing for tunas is the longline. In addition to tunas the longline catches other large pelagic predators such as billfishes and sharks whose habitats overlap those of the tunas. The nonspecific nature of longline catches created a problem of finding a way to regulate fishing for billfishes without interfering with tuna fishing operations. The Preliminary Management Plan which provides interim regulations for billfishes, sharks, wahoo, Acanthocybium solandri, and mahimahi, Coryphaena hippurus, until the FMP for these species is developed, handles the problem by declaring nonretention zones within the FCZ. In these zones all billfishes caught beyond a species quota are to be returned to the sea whether they are alive or not.

The effectiveness of a policy of nonretention as a conservation measure depends upon the number of live releases. This study reports on the numbers of live and dead billfishes by species caught on a series of longline sets and investigates some of the factors which may be related to a fish being alive or dead at the time of boating. Billfish species in the Pacific Ocean are: swordfish, Xiphias gladius; sailfish, Istiophorus platypterus; shortbill spearfish, Tetrapturus angustirostris; striped marlin, T. audax; black marlin, Makaira indica; and blue marlin, M. nigricans.

SOURCES AND DESCRIPTION OF DATA

Data were obtained from three sources: the Honolulu Laboratory (HL), the Far Seas Fisheries Research Laboratory (FSFRL) of Japan, and the Southeast Fisheries Center (SEFC) of the National Marine Fisheries Service. The data from HL came from detailed records of exploratory longline fishing

LIBRARY
NATIONAL MARINE FISHERIES SERVICE
HONOLULU LAB

expeditions in the Pacific Ocean between 1950 and 1970 inclusive from ships operated by or chartered by the HL. The data from FSFRL and SEFC were summaries of live and dead billfishes on longline gear. The data from Japan were collected on exploratory research expeditions in the Pacific and Atlantic Oceans during the period 1952-66. The data from SEFC were collected by U.S. observers placed on commercial Japanese longline vessels fishing in the Atlantic Ocean and the Gulf of Mexico during 1978. Species of billfish caught in the Atlantic Ocean are: swordfish; Atlantic sailfish; longbill spearfish, T. pfluegeri; white marlin, T. albidus; and blue marlin.

On the HL fishing expeditions, descriptions of each longline set were systematically recorded in detail by highly trained observers. Recorded information used in this study are:

1. Date.
2. Location.
3. Description of gear details.
4. Beginning and ending times of each set.
5. Time each basket was hauled.
6. Sea-surface temperature at positon of first basket hauled.
7. Species of each fish caught.
8. Size (length, weight, or both) of some of the fish caught.
9. Sex of some of the fish caught.
10. Position of hook on which fish was caught.
11. Condition of fish at time of boating, e.g., alive, dead, shark damaged.

Typically the line was set before dawn and retrieval began at noon. Retrieval time depended upon the number of baskets set, the amount of breaks and tangles of the line encountered during hauling, and the number of large fish caught. The length of the mainline was 384 m (210 fathoms) per basket. Sixty baskets were used on most sets. The length of the floatline was 18.3 m (10 fathoms) except when it was varied experimentally. The number of evenly spaced hooks in a basket varied from 6 to 21 but was 6 most of the time. The length of the gangions was inversely related to the number of hooks in a basket to prevent adjacent hooks from tangling.

On a standardized log for longline sets the observer routinely described the gear variables such as the number of baskets, number of hooks per basket, and length of floatlines for each set. He recorded the times

for the beginning and the ending of the gear setting operation. During the retrieval process he recorded the time when each buoy was brought in. Since the baskets of gear are separated by these buoys, the times represent the start and end of the hauling of each basket. The observer also carefully monitored the hooks as they were retrieved so that he knew which hook and which basket caught any given fish.

Sea-surface temperatures were measured with a bucket thermometer to accompany the thermograms which were obtained just before line retrieval began.

Fish were weighed on a steelyard. The fish weights are expected to have varying amounts of error depending on the sea state and roll characteristics of the ship. The error is presumed to be small and unbiased. Sex of the fish was determined by examination of the gonads.

TREATMENT OF DATA

Chi-square tests and analyses of variance, whichever was appropriate, were applied to HL data to determine if the proportion of fish which reached the ship alive was associated with the following variables: size, sex, species, location, time of year, depth of capture, and fishing time. Possibilities of interactions among variables affecting the proportion of live fish were not investigated because of insufficient data. Data from the other two sources were not detailed enough to be included in the analyses above. They were compared with data from the HL, however, to determine if the proportions of live fish from the three sources were significantly different.

Locations of capture were grouped into three broad zones for the analyses. The three areas are: north of lat. 10°N, 10°N-10°S, and south of 10°S.

Time of year was grouped into quarters of the year beginning with January.

Depth of capture was derived from data on position of the fish-catching hook and length of the floatline. Depth from hook position was calculated from the catenary model assuming a distance of 293 m (160 fathoms) between buoys. This distance was the median of distance between buoy measurements by Murphy and Shomura (1953, 1955). The length of the floatline was added to the depth calculated from hook position. Three main sources of error which cause the approximated depth of capture to differ from the real depth of capture are: (1) variability in the distance between buoys in which case the overestimations should equal the underestimations; (2) currents causing the line to hang at some angle other than vertical, in which case all errors would be overestimates; and (3) fish getting caught while the line was being set or retrieved and not while it was at its maximum depth, in which case all errors would be overestimates. For the chi-square test the depths were grouped into three categories: 0-74 m (0-40 fathoms), 75-129 m (41-70 fathoms), and greater than 129 m.

Fishing duration is defined in this study as the length of time during which a hook may catch a fish. It is a variable associated with each individual hook and does not refer to the time the entire gear is in the water nor the duration of the longline expedition. It was calculated by subtracting the time at the end of the set from the time the front end of the basket containing the hook reached the ship.

RESULTS

Species

The HL data included observations on 933 billfishes. The percent living at time of boating ranged from 18% for sailfish to 54% for striped marlin (Table 1). A highly significant chi-square indicated that the proportion living is dependent on species. Striped marlin, however, was the only species having a significantly different percentage alive. When the striped marlin data were excluded, the chi-square value was 6.42 ($0.2 > P > 0.1$).

Table 1.--Numbers of longline caught billfishes alive and dead by species.

Species	Alive	Dead	Percent alive
Sailfish	10	46	17.9
Shortbill spearfish	36	76	32.1
Black marlin	9	26	25.7
Blue marlin	110	268	29.1
Striped marlin	170	142	54.5
Swordfish	16	24	40.0
$\chi^2 = 62.48$, d.f. = 5, $P < 0.01$			

Areas

As mentioned earlier the locations of capture were grouped into three categories: north of lat. 10°N, 10°N-10°S, and south of 10°S. Except for blue marlin, catches for the area south of lat. 10°S were too small for statistical testing. For all species the percent alive in the northern area was smaller than that in the equatorial area (Table 2). Only in the case of the black marlin, however, was the difference between the areas great enough to be significant.

Seasons

The numbers alive and dead are tabulated by species and the chi-square tests indicated that the percent alive was independent of the time of year (Table 3).

Table 2.--Numbers of longline-caught billfishes alive and dead by areas.

Species	Latitude north of 10°N		Latitude 10°N-10°S		Latitude south of 10°S	
	Alive	Dead	Alive	Dead	Alive	Dead
Sailfish	6	32	4	9	0	5
Shortbill spearfish	7	22	29	47	0	7
Black marlin	5	25	3	1	1	0
Blue marlin	69	201	28	38	13	29
Striped marlin	34	35	136	106	0	1
Swordfish	7	15	9	9	0	0

Sailfish	$\chi^2 = 1.38$, d.f. = 1, $0.2 < P < 0.3$
Shortbill spearfish	$\chi^2 = 1.83$, d.f. = 1, $0.1 < P < 0.2$
Black marlin	$\chi^2 = 6.67$, d.f. = 1, $P < 0.01$
Blue marlin	$\chi^2 = 7.39$, d.f. = 2, $0.02 < P < 0.05$
Striped marlin	$\chi^2 = 1.04$, d.f. = 1, $0.3 < P < 0.5$
Swordfish	$\chi^2 = 1.36$, d.f. = 1, $0.2 < P < 0.3$

Table 3.--Numbers of longline-caught billfishes alive and dead by quarters of the year.

Species	Jan.-Mar.		Apr.-June		July-Sept.		Oct.-Dec.	
	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
Sailfish	4	8	0	2	1	6	1	4
Shortbill spearfish	22	21	8	13	6	4	0	11
Black marlin	2	3	2	4	3	3	2	1
Blue marlin	42	109	17	46	28	75	23	38
Striped marlin	103	64	24	19	12	15	31	44
Swordfish	4	5	6	6	2	8	4	5

Sailfish	$\chi^2 = 0.14$, d.f. = 2, $0.90 < P < 0.95$
Shortbill spearfish	$\chi^2 = 1.56$, d.f. = 2, $0.3 < P < 0.5$
Black marlin	$\chi^2 = 1.01$, d.f. = 3, $0.7 < P < 0.8$
Blue marlin	$\chi^2 = 2.63$, d.f. = 3, $0.3 < P < 0.5$
Striped marlin	$\chi^2 = 4.38$, d.f. = 3, $0.2 < P < 0.3$
Swordfish	$\chi^2 = 2.31$, d.f. = 3, $0.5 < P < 0.7$

Depth of Capture

Table 4 shows the numbers of live and dead fish by species caught in the three depth categories. Except for shortbill spearfish, the condition of being alive or dead was not dependent on depth of capture. Shortbill spearfish, on the other hand, had a greater tendency to be alive the deeper they were caught.

Table 4.--Numbers of longline caught billfishes alive and dead by depth of capture.

Species	Depth of capture (m)					
	0-74		75-129		>129	
	Alive	Dead	Alive	Dead	Alive	Dead
Sailfish	3	16	3	19	4	11
Shortbill spearfish	5	23	15	35	16	18
Black marlin	2	10	6	9	1	7
Blue marlin	34	79	42	111	34	78
Striped marlin	48	32	68	66	54	44
Swordfish	3	9	7	7	6	8

Sailfish	$\chi^2 = 1.12$, d.f. = 2, $0.5 < P < 0.7$
Shortbill spearfish	$\chi^2 = 6.19$, d.f. = 2, $0.02 < P < 0.05$
Black marlin	$\chi^2 = 2.85$, d.f. = 2, $0.2 < P < 0.3$
Blue marlin	$\chi^2 = 0.34$, d.f. = 2, $0.8 < P < 0.9$
Striped marlin	$\chi^2 = 1.75$, d.f. = 2, $0.3 < P < 0.5$
Swordfish	$\chi^2 = 1.76$, d.f. = 2, $0.3 < P < 0.5$

Surface Temperatures

The range of surface temperatures at the locations where the longline was set varied with the three areas. North of lat. 10°N the range was 22.9°-29.2°C with 96% of the observations above 25.0°C. Between lat. 10°N and 10°S surface temperatures ranged from 15.8° to 29.0°C with 96% of the temperature records higher than 23.0°C. South of lat. 10°S the surface temperature range was 22.9°-29.8°C. Within those temperature ranges, whether the fish was alive or dead when it was brought alongside the ship was not a function of surface temperature.

Size

Comparisons were made of the sizes of live fish and dead fish. For blue marlin, striped marlin, and shortbill spearfish, the mean sizes of the live fish were greater than the mean sizes of the dead fish while the reverse was true for black marlin and sailfish (Table 5). Only in the case of the blue marlin was the difference statistically significant ($P < 0.05$). Apparently, large blue marlin are more likely to survive the capture process than smaller ones. The relationship is indicated coarsely in Figure 1 in which the percent of live fish is grouped in 100-lb classes and plotted against mean weight.

Fishing Duration

The mean fishing duration for hooks that returned dead fish was higher than the mean fishing duration of hooks that returned live fish (Table 6). Although this was true for all species, only in the cases of sailfish and blue marlin were the differences significant at the 0.05 probability level.

Table 5.--Numbers, mean weights, and standard deviations of live and dead billfishes caught on longlines.

Species	Number in sample		Mean weight (kg)		Standard deviation	
	Alive	Dead	Alive	Dead	Alive	Dead
Sailfish	3	5	21.3	25.7	2.53	10.52
Shortbill spearfish	14	9	14.0	13.8	3.52	3.92
Black marlin	3	9	65.6	142.1	61.23	61.44
Blue marlin	20	35	114.9	76.4	73.20	42.66
Striped marlin	46	14	47.6	35.7	30.57	23.01

Sailfish	F = 0.48
Shortbill spearfish	F = 0.02
Black marlin	F = 3.49
Blue marlin	F = 6.08*
Striped marlin	F = 1.82

*Significant at 0.05 level.

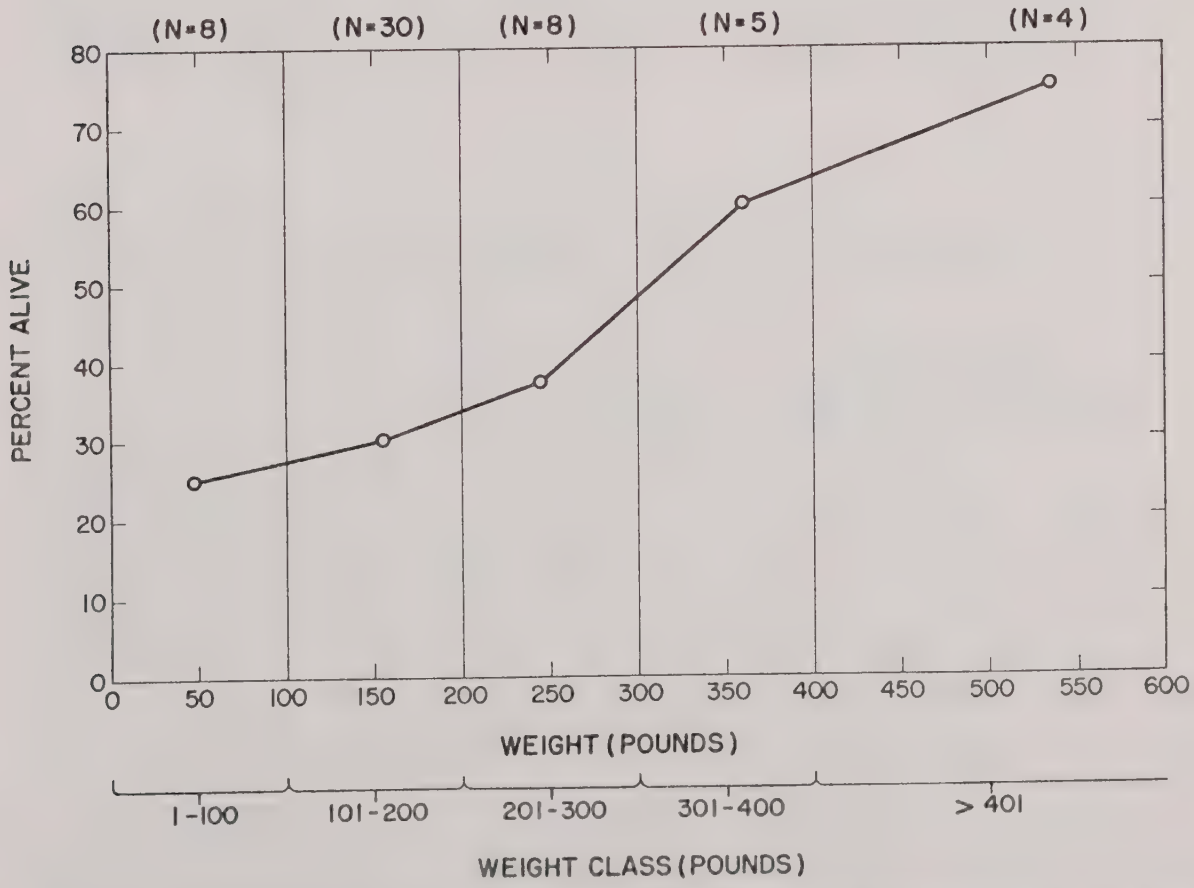


Figure 1.--Survival of blue marlin captured on longline as related to fish size.

Table 6.--Numbers, mean fishing duration, and standard deviation of live and dead billfishes caught on longlines.

Species	Number in sample		Mean fishing duration (h)		Standard deviation		F value
	Alive	Dead	Alive	Dead	Alive	Dead	
Sailfish	10	30	7.52	8.55	1.070	1.203	5.84*
Shortbill spearfish	35	42	8.70	9.02	1.359	1.140	1.25
Black marlin	8	11	8.87	9.41	0.809	1.360	0.94
Blue marlin	109	145	8.29	8.77	1.336	1.518	6.62*
Striped marlin	158	92	8.50	8.83	1.397	1.372	3.22
Swordfish	12	7	8.29	9.96	1.425	2.562	3.40

*Significant at 0.05 level.

Sources of Data

The data from the three sources (Table 7) were compared species by species. Because the data from the HL and the SEFC were from separate oceans with only two species common to both oceans, there were only two comparisons of the HL data and the SEFC data. All other comparisons involved the FSFRL data.

Table 7.--Numbers of live and dead billfishes caught on longlines by source of data; HL (Honolulu Laboratory), FSFRL (Far Seas Fisheries Research Laboratory), and SEFC (Southeast Fisheries Center).

Species	Pacific Ocean				Atlantic Ocean			
	HL		FSFRL		SEFC		FSFRL	
	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
Sailfish	10	46	84	147	72	74	7	7
Shortbill spearfish	36	76	131	156	--	--	--	--
Longbill spearfish	--	--	--	--	36	68	46	29
Black marlin	9	26	435	379	--	--	--	--
Blue marlin	110	268	674	512	114	158	8	0
Striped marlin	170	142	554	168	--	--	--	--
White marlin	--	--	--	--	447	682	26	13
Swordfish	16	24	86	49	309	643	2	3

Sailfish	$\chi^2 = 18.47$, d.f. = 3, $P < 0.01$
Shortbill spearfish	$\chi^2 = 6.03$, d.f. = 1, $0.01 < P < 0.02$
Longbill spearfish	$\chi^2 = 12.53$, d.f. = 1, $P < 0.01$
Black marlin	$\chi^2 = 10.34$, d.f. = 1, $P < 0.01$
Blue marlin	$\chi^2 = 102.76$, d.f. = 3, $P < 0.01$
Striped marlin	$\chi^2 = 51.35$, d.f. = 1, $P < 0.01$
White marlin	$\chi^2 = 11.47$, d.f. = 1, $P < 0.01$
Swordfish	$\chi^2 = 50.06$, d.f. = 3, $P < 0.01$

Generally, the proportion of live fish returned by the longlines of the HL was considerably lower than the others and the proportion of live fish returned by the longlines of the FSFRL was considerably higher than the others. The comparison between the data from these two laboratories resulted in chi-square values beyond the 0.01 probability level for sailfish, black marlin, blue marlin, striped marlin, and swordfish, and beyond the 0.02 probability level for the shortbill spearfish.

Chi-square tests of live billfishes returned by the Japanese research ships as compared to Japanese commercial ships in the Atlantic Ocean were highly significant for longbill spearfish, blue marlin, and white marlin and insignificant for sailfish and swordfish.

DISCUSSION

Eight variables were investigated for their effect on billfishes caught on longlines arriving at the fishing vessel alive. The most important variable in this respect was sources of data. That the proportion of live billfishes brought to the ship should differ with the three longline fishing groups, i.e., the HL experimental, the FSFRL experimental, and the Japanese commercial, is not altogether unexpected because each group probably has its own gear design, handles the line differently, and fishes different amounts of gear.

On the basis of amount of gear fished the results were surprising. On the average the HL ships set 60 units of gear, the FSFRL ships set 100 units of gear, and Japanese commercial ships set 300 units of gear. Because the rate of live fish is related to fishing duration and fishing duration is proportional to the amount of gear set, one would expect the highest return of live billfishes to be from the HL ships. In actuality it had the least. I have no explanation for this.

The mean fishing duration for dead fish was consistently longer than the mean for live fish although the difference was statistically significant for only two species. The survival of caught fish is expected to be a function of how long the fish was on the line from the time it was hooked to the time it was pulled to the ship which in turn was a function of fishing duration. If, for example, the probability of catching a fish on a given hook is equal for all instants of time that the hook is in the water, i.e., a fish is just as likely to strike a hook at one instant of time as any other instant of time, then the average length of time a fish is on the line hypothetically would be one-half of fishing duration. I expect, however, that the probability function of when a hook catches a fish to be much more complex than the example given and would include such factors as the diffusion rate of bait odors and the attractiveness and condition of the bait used.

This study has shown that the greatest difference in the proportion of live billfishes brought to the ship depends on who is doing the fishing. This being the case, it would be inappropriate to apply the results of one fishery to another, such as attempting to predict the number of live billfishes expected in the Japanese commercial longline fishery in the Pacific Ocean from the results of the HL data or the FSFRL data.

LITERATURE CITED

Murphy, G. I., and R. S. Shomura.
1953. Longline fishing for deep-swimming tunas in the central Pacific, January-June 1952. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 108, 32 p.
1955. Longline fishing for deep-swimming tunas in the central Pacific, August-November 1952. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 137, 42 p.

LIBRARY
NATIONAL MARINE FISHERIES SERVICE
HONOLULU LABORATORY
P. O. BOX 3830
HONOLULU, HAWAII 96812

P R O J E C T R E P O R T

OCT 17 1980

Submitted to

National Marine Fisheries Service, Honolulu Laboratory

Research Topic: Reproduction of Tuna in Captivity, Induced Spawning and Larval Rearing

Project Period: June 1 to July 31, 1980

Submitted by:

Calvin M. Kaya, Ph.D.

Associate Professor of Zoology

Montana State University

Bozeman, Montana 59717

Telephone Number 406-994-4548

These investigations took place in Honolulu, Hawaii at the Kewalo Research Facility of the National Marine Fisheries Service. Six deliveries of live skipjack tuna were received during June and July 1980 from two local commercial fishing vessels, the Bluefin and the Neptune. The fish were caught by standard pole-and-line methods and transported to the receiving dock of the laboratory in live baitwells. All the specimens were between 40 and 50 cm in fork length and 1.4 to 2.2 kg in weight; fish of this size are about the largest that can be kept alive in reasonable condition in the baitwells of these vessels (about 145 X 165 X 130 cm deep in the Bluefin). Skipjack of this size are between one and two years old and probably in their first spawning season (Brock 1954; Yoshida 1966, 1971).

Gonadal maturation states of females were determined at various times following their capture, as will be specified, either through biopsies of live specimens or through postmortem dissections. Biopsies involved extraction of gonadal tissue by catheterization through the urogenital pore of restrained, unanesthetized fish (Shehadeh et al. 1973). Ova were teased free from unpreserved, fresh or refrigerated ovarian tissue placed in 0.9% saline solution and the diameters of 25 each from the first and second largest developing groups were measured with an ocular micrometer. Ovarian maturation stages of skipjack tuna have been described by several investigators (Buñag 1956; Shaefer and Orange 1956; Raju 1964; Yoshida 1966; Simmons 1969; Batts 1972). Since the occurrence and progress of ovulation was a primary interest of this study, females were divided into the following categories:

1. Unovulated. Ripe ova are not found loose in the ovarian lumen. Maturing ova vary in size according to maturation state of the female, the largest group of ova ranging from .10 mm or less in immature

specimens to about .90 mm in specimens nearing ovulatory condition. Biopsies of live females yield ovarian tissue, consisting mostly of developing ova within follicles, in the catheter. Dissections reveal ovaries that are yellow, firm, and of varying sizes depending on maturation state.

2. Ovulating, not yet running ripe. Some ripe ova are found loose in the ovarian lumen; females release few to no ripe ova on moderate to firm stripping pressure. Biopsies produce a mixture of ripe ova and enlarged, preovulatory ova in the catheter from females that are just starting to ovulate, and only ripe ova in those that already have considerable numbers of ova released into the lumen. Dissections reveal ovaries that are bright yellow, swollen, and soft. The ovarian walls are greatly thickened with the presence of the enlarged, preovulatory ova.

3. Ovulated, running ripe. Ovaries are swollen with ripe, ovulated ova which can be readily expressed from the females with slight to moderate stripping pressure. Females of the size used in this study could be stripped of about 100,000 to over 150,000 ova when in this state. Biopsies yield only ripe ova in the catheter. Dissections reveal ovaries that are extremely swollen, soft, and with a yellow, slightly transluscent appearance. The ovarian lumen is greatly enlarged with the mass of ripe ova.

4. Recently spent. Ovaries contain a few to a few thousand ova loose in the lumen. Moderate to firm stripping pressure produces from no ova to a few thousand from the females. Ova appear normal in those which have spawned within a few hours previously, but have indented or

collapsed membranes in those examined later. Biopsies yield residual ova, or a mixture of residual ova and ovarian tissue containing the next group of developing ova, in the catheter. Dissections reveal ovaries that are soft, flaccid, and bloody in appearance.

The first group of skipjack were delivered to the laboratory on the night of June 18 and were biopsied at 9:30 the next morning. The purpose of this biopsy was to determine whether any females had ovaries sufficiently mature to make them suitable for hormonally induced spawning trials. However, all 8 females biopsied turned out to be recently spent. (There were actually 10 females in the group, as later determined by dissections, but for various reasons not all specimens in a group are successfully biopsied during any given session. Some struggle too violently to be effectively handled, and others are released after an unsuccessful biopsy attempt. Male skipjack of the size used in this study are difficult to biopsy because of the small size of their urogenital aperture, and specimens in which the catheter could not readily be inserted were released as probable males. On postmortem examination some of these would later turn out to be females, the number depending on the skill and experience of the investigator and the circumstances attending the given biopsy session. These other two females were examined five days later and also turned out to be spent.)

The spent condition of all the females was a disappointment at the time since it meant that none could be used for hormonally induced spawning attempts. I recalled that we had previously biopsied one other group of skipjack on the morning following their capture and delivery, during the preceding June of 1979, and all three females in that group also had been recently spent. The spent condition of all these females contrasted sharply with the maturing ovaries of similar sized specimens being concurrently sampled from the local cannery

(M. Queenth, National Marine Fisheries Service, Honolulu, Hawaii, unpublished data). These observations suggested that the skipjack might be spawning during their first night in captivity, a possibility strengthened by a report that anchovies (Engraulus mordax) will do so (Hunter and Goldberg, 1980).

When the next group of 13 live skipjack were delivered to the laboratory the evening of June 28, I set up a siphon and strainer to sample water from their holding tank. The strainer was checked at 6:05 the following morning and was found to contain more than 100,000 ova. The fish were biopsied that same morning and three females were found, all recently spent. Two other specimens, females, had died during the transfer from the fishing vessel to the holding tank at a time about 8 hr following their capture. When their refrigerated ovaries were examined the next morning, both pairs were found to be in a running ripe condition, swollen with masses of ovulated ova. These observations demonstrated that the skipjack were indeed spawning during the first night in captivity, and also suggested that females could be in a running ripe condition within 8 hr following their capture.

Before the next delivery of live skipjack, the boat captains involved were asked to immediately refrigerate specimens taken from the same school so that the gonadal condition of freshly captured fish could be determined. The next delivery, of 8 skipjack, was received on July 15. They had been captured at about 4:30 p.m. and were delivered at the laboratory dock at about 8:00 p.m. The 8 fish were watched for any spawning behavior in their holding tank until 12:30 a,m., but none was observed. At this time, 8 hr after capture, the fish were biopsied. Three were determined to be females, of which two were running ripe while the other had not ovulated. Three males were identified by the

presence of milt in the catheter, but none could be stripped of milt. Two males were sacrificed and their testes dissected out. About 100,000 ova were stripped from each of the two ripe females and fertilized with milt squeezed from the dissected testes. Both females were also sacrificed after being stripped. Again, large numbers of ova were found the next morning in the strainer sampling water from the holding tank. Two other females had remained in the tank and died the second day following capture. Both were found to have spent ovaries and were therefore responsible for the ova spawned out in the holding tank.

Thirteen refrigerated specimens were received at the same time, four females and nine males. The four females provided a distinct contrast to those that had been kept alive for 8 hr. All four had not ovulated and instead had ovaries containing maturing ova with the largest group averaging from .59 to .62 mm in diameter. All males had mature testes grossly indistinguishable from those of the males sacrificed 8 hr following capture.

Three more groups of both live and refrigerated specimens were received on July 21, 22, and 31, and in each instance produced results similar to those of July 15. Observations on all six groups of female skipjack received from June 18 to July 31 are summarized in Table 1. None of the 16 specimens killed and refrigerated on capture were in an ovulatory state. The largest group of maturing ova averaged .59 to .64 mm in 14 of these females and .74 mm in another, while the remaining individual had relatively immature ovaries (Table 2). Nine females were placed in refrigeration after dying in transit to the laboratory, with times of death not recorded by the fishing crews but less than five hr in all cases. None of these females had yet ovulated, and their largest group of developing ova averaged from .60 to .93 mm in diameter (Table 2).

Table 1. Ovulatory Status of Skipjack Tuna at Different Times Following Capture during June and July 1980.

	No.	Not Ovulated	Ovulating, Not Yet Running Ripe	Ovulated, Running Ripe	Recently Spent
Refrigerated Immediately After Capture	15	15	0	0	0
Captive Females, 0 to 5 Hr After Capture[1]	9	9	0	0	0
Captive Females, 5 to 6 Hr After Capture	13	1	12	0	0
Captive Females, 7 to 8.5 Hr After Capture	12	3	1	8	0
Captive Females, 15 to 65 Hr After Capture	20	1	0	0	19

[1]Refrigerated after dying in transit to the laboratory, individual times of death not known but less than 5 hr in all cases.

Table 2. Mean Sizes (mm)[1] of Largest and Second Largest Modal Group of Developing Ova in Skipjack Tuna Killed and Refrigerated Immediately After Capture, or Refrigerated After Dying in Transit to the Laboratory.

	Refrigerated on Capture			Died in Transit			
Date	No.	Largest Group	Second Group	No.	Time (hr)[2]	Largest Group	Second Group
July 15	4	.62	not measured				
		.61	" "				
		.59	" "				
		.60	" "				
July 21	7	.60	.42				
		.60	.39				
		.60	.40				
		.59	.41				
		.59	.40				
		.60	.39				
		.59	.40				
July 22	3	.22	.10	7	< 4.5	.84	.44
		.64	.41			.93	.43
		.74	.44			.76	.44
						.69	.44
						.72	.42
						.70	.42
						.72	.45
July 31	2	.62	.41	2	< 5	.67	.41
		.62	.43			.60	.41

[1] standard deviations .02 to .04

[2] time between capture and death

With those kept alive all but one of the 13 specimens examined 5 to 6 hr after capture were ovulating but not yet running ripe, and 8 of 12 examined after 7 to 8,5 hr were running ripe. All but one of 20 specimens examined 15 to 65 hr after capture were spent. On all five occasions when the holding tanks were monitored for the presence of spawned ova, large numbers of ova were evident by the morning following delivery.

These observations clearly demonstrated that female skipjack tuna caught during this time of the year responded to some factor associated with being captured or confined by undergoing the final stages of ovarian maturation and ovulating ripe ova into the ovarian lumen. This response could be completed within 8 hr. Unless manually stripped the females proceeded to spawn out these ova into the holding tank and by the next day, 15 to 24 hr after capture, were in a spent condition with from few to a few thousand residual ova loose in the ovarian lumen.

Numerous investigators have described the multimodal size distribution of developing ova in ovaries of maturing tuna. The entire complement of the most advanced group of ova (about .60 mm or greater in these specimens) appeared to undergo final maturation and ovulation in this "stress response", but the second largest group seemed not affected. Ovaries from "control" specimens killed and refrigerated on capture and from those that died within 5 hr contained an advanced group of maturing ova, as previously described, and a second, smaller group that averaged between .39 and .44 mm in diameter (Table 2). Ovaries from fully ovulated, running ripe females and from those recently spent contained a residual group of similar, unovulated ova that averaged .39 to .44 mm in diameter (Table 3).

Table 3. Mean Sizes (mm)[1] of Largest Modal Group of Unovulated Ova in Running-Ripe or Recently Spent Skipjack.

Date	Hr After Capture	Status	Ova Diameter
June 28	8	running ripe	.46
	8	running ripe	.46
July 17	46	spent	.43
	46	spent	.40
July 21	7	running ripe	.43
July 22	20.5	spent	.42
	25	spent	.39
July 23	32-39[2]	spent	.40
	"	spent	.43
	"	spent	.49
July 31	6.5-15[2]	spent	.45

[1]Standard deviations .02 to .04

[2]Found dead in holding tanks, time interval since last seen alive

Testes of males sacrificed after 7 to 8.5 hr appeared identical to those sacrificed and refrigerated on capture. All males had testes that were mature, white, and firm and had a thick, viscous milt in the sperm ducts. None of the males yielded milt on moderate stripping pressure. This indicates that either the males do not have a corresponding seminal hydration response to capture and confinement, or that their response occurs very quickly after capture and their testes recover to an original appearance within a few hours. Despite this seeming lack of response by the males and although we did not observe any apparent spawning behavior in the holding tanks, a very small fraction of eggs released spontaneously into the holding tanks and recovered by the strainer were found to be fertilized and undergoing embryonic development (e.g. less than 50 found among about 100,000 collected in the strainer the morning of June 29).

The ovulated ova, both those released spontaneously into the tanks and those stripped from ripe females, were normal in size and appearance. They were spherical, transparent, averaged around 1.0 mm in diameter, and had a single oil globule about .24 mm in diameter. The fertilization rates of ova stripped out of females about 8 hr following their capture were only about 40 to 50%, but this may reflect the quality or quantity of the small amounts of viscous milt squeezed from the dissected testes. The embryos hatched out in about 30-31 hr at 25-26^{o}C, and started feeding on the third day after hatching. Although they fed actively on rotifers (Brachionus sp.) and copepod nauplii, we did not manage to rear any beyond the 12th day after hatching. Rearing trials are expected to continue.

Conclusions

1. The "stress-induced" maturation and ovulation of skipjack tuna, discovered and documented by this study, means that fertilized eggs, embryos, and larvae can be produced reliably and predictably from captive specimens of this species.
2. Questions remain to be resolved (see recommendations) in order to better understand this phenomenon and to determine or improve the predictability of this response relative to time of day, season, and year.
3. Because of the inability of the laboratory to obtain live kawakawa from the commercial fishing boats during the study period and because of the ovulatory response and consequent spent condition of the skipjack females, appropriately mature females were not available for hormone-induced spawning trials on either species. However, inducement of spawning through hormone treatments, although demonstrated to be feasible with kawakawa (Kaya et al, 1981), now appears an academic problem no longer necessary for practical spawning operations with skipjack tuna.
4. Attempts to rear skipjack larvae have not yet produced survival beyond the 12th day following hatching, even though the larvae appeared normal and healthy and fed actively. Solution of this aspect will depend on further rearing trials, experimentation with different larval foods, monitoring of water quality in the rearing tanks, and determination of possible effects of egg quality on larval viability (see recommendations).

Recommendations

Since fertilized eggs of skipjack tuna can now be produced "on demand" at least during the summer months, a broad spectrum of experimental observations on embryos, larvae, and (with the development of effective rearing techniques) juveniles will be made possible. To better define the potentials for and the limitations of applying this ovulatory response to such practical purposes, I recommend that priority be given to continuing or initiating the following studies at the Kewalo Research Facility:

1. The larval rearing efforts should be continued and given highest priority, With access to fertilized eggs now assured, these efforts should eventually develop effective procedures and provide the means to produce advanced young routinely.
2. The relationship should be determined between the annual reproductive cycle of skipjack in Hawaiian waters and the availability of responsive females. The following should be done toward this objective:
   A. Weekly sampling of ovaries from skipjack delivered to the cannery should be continued at least until August 1981.
   B. Live skipjack should be obtained on at least a monthly basis until August 1981 and each group received should be subjected to the routine egg monitoring (siphon and strainer) and biopsy and stripping techniques to test for ovulation.

   These observations should provide the following:

   (1) Determine the portion of the year when skipjack can be expected to undergo the ovulatory response.

(2) Determine the size to which ova must develop before the females will respond, and the occurence of females advanced to this state at different times of the year.

(3) Provide larvae for further rearing trials.

3. An attempt should be made to determine whether there is a relationship between maturity of ova (as indicated by size of largest maturing group) and fertilization rate, hatching success, and time of survival of larvae. This could be examined by comparing the ova diameters from refrigerated specimens and the fate of fertilized eggs and larvae produced from members of the same school.

4. Responsiveness of other species of tuna should be tested:

   A. Kawakawa should be obtained during the spring and summer breeding season and subjected to the same procedural routine to determine whether they will also undergo an ovulatory response to capture.

   B. Consideration should be given to designing a similar experiment to be conducted at sea, either on a ship with a large baitwell or through the use of a floating enclosure, on larger species like yellowfin tuna.

5. The relationship between time after capture and stages of ovarian response should be better defined, This would involve periodic sampling of captive fish until specimens bcome running ripe. Because of the short time to completion of the response, such observations would have to be conducted, or at least initiated, on board the fishing vessel.

References Cited

Batts, B. S. 1972. Sexual maturity, fecundity, and sex ratios of the skipjack tuna, Katsuwonus pelamis (Linnaeus), in North Carolina Waters. Trans. Am. Fish. Soc. 101(4);626-637.

Brock, V. E. 1954. Some aspects of the biology of the aku, Katsuwonus pelamis, in the Hawaiian Islands. Pac. Sci. 8(1): 94-104.

Buñag, D. M. 1956. Spawning habits of some Philippine tuna based on diameter measurements of the ovarian ova. Philipp. J. Fish. 4(2): 145-175.

Hunter, J. R. and S. R. Goldberg. 1980. Spawning incidence and batch fecundity in northern anchovy, Engraulis mordax. Fish. Bull. 77(3): 641-652.

Kaya, C. M., A. E. Dizon, and S. Hendrix. 1981. Induced spawning of a tuna, Euthynnus affinis. Fish. Bull. 78(1): (in press).

Raju, G. 1964. Studies on the spawning of the oceanic skipjack Katsuwonus pelamis (Linnaeus) in Minicoy waters. Symposium on Scombrid Fishes, Part II, Mar. Biol. Ass., India: 725-732.

Schaefer, M. B. and C. J. Orange. 1956. Studies on the sexual development and spawning of yellowfin tuna (Neothunnus macropterus) and skipjack (Katsuwonus pelamis) in three areas of the eastern Pacific Ocean, by examination of gonads. Bull. Inter-Am. Trop. Tuna Comm. 1(6): 281-349.

Shehadeh, Z. H., C.-M. Kuo, and K. K. Milisen. 1973. Validation of an in vivo method for monitoring ovarian development in the grey mullet (Mugil cephalus L.). J. Fish Biol. 5: 489-496.

Simmons, D. C. 1969. Maturity and spawning of skipjack tuna (Katsuwonus pelamis) in the Atlantic Ocean, with comments on nematode infestation of the ovaries. U. S. Fish Wildl. Serv., Spec. Sci. Rep., Fish. (580): 17 p.

Yoshida, H. O. 1966. Skipjack tuna spawning in the Marquesas Islands and Tuamotu Archipelago. U. S. Fish Wildl. Serv., Fish. Bull. 65(2): 479-488.

Yoshida, H. O. 1971. The early life history of skipjack tuna, Katsuwonus pelamis, in the Pacific Ocean. Fish. Bull. 69(3): 545-554.

GEAR COMPETITION IN LOBSTER TRAPPING IN THE NORTHWESTERN HAWAIIAN ISLANDS

Jeffrey J. Polovina
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service
Honolulu, Hawaii 96812

NOV 18 1980

November 1980

INTRODUCTION

The gear used to catch the spiny lobster, Panulirus marginatus, in Hawaii is a wire mesh two-chambered California style trap (pot). Commercial fishermen use a string of these traps with as many as 250 traps equally spaced on a single line.

Each lobster trap exploits a population of lobsters within a certain radius of the trap. If the traps are sufficiently close to one another, then the area exploited by two or more traps overlap and we say there is gear competition. In this report, we will examine the relationship between trap spacing on a string and lobster catch per trap. We will use data collected from the RV Townsend Cromwell and data provided by commercial fishermen.

THE MODEL AND DATA

Suppose traps are set at I locations (stations) and suppose at each location (i), J different spacings are tested with K traps per string. Let C_{ijk} be the number of lobsters caught in the k^{th} trap (k = 1, ..., K) with spacing j (j = 1, ..., J) at location i (i = 1, ..., I). Then C_{ijk} can be expressed as

$$C_{ijk} = B_o + B_i^L + B_j^S + B_k^T + B_{ij}^{LS} + B_{ik}^{LT} + B_{jk}^{ST} + B_{ijk}^{LST} + e_{ijk}$$

where

B_o = overall mean catch per trap

B_i^L = location effect

B_j^S = spacing effect

B_k^T = trap position on string effect

B_{ij}^{LS} = location-spacing interaction effect

B_{ik}^{LT} = location-trap position interaction effect

B_{jk}^{ST} = spacing-trap position interaction effect

B_{ijk}^{LST} = spacing-location-trap position interaction

e_{ijk} = error random variable which is normally distributed

We are primarily interested in testing $H_o : B_j^S = 0$ for all j.

We have catch data collected from the Townsend Cromwell for 10 locations with one string consisting of 8 traps per string set at each of 5 spacings per location. The trap spacing tested were 10, 15, 20, 25, and 30 fathoms between traps.

The commercial data were obtained at six locations using approximately 20 traps per string with trap spacings set at 10 and 30 fathoms. At two of these six locations, spacing of 20 fathoms between traps was also used.

All data were collected at locations in the Northwestern Hawaiian Islands.

ANALYSIS

Research Data

A three-way ANOVA was used with catch rate per trap as the dependent variable and spacing, location, and position on the string as factors or treatments. Location and location-spacing interaction effects were significant ($P < 0.001$) while the trap position on string effect was not significant ($P > 0.05$). The lack of a trap position on string effect on catch rate per trap makes it possible to consider each trap on a string as a replicate for each location and spacing. Pooling across trap position

reduces the three-way ANOVA to a two-way ANOVA with spacing and location treatments and eight observations (replicates) per cell. The significant location effect and location-spacing interaction effect suggest that the locations may represent sites with different lobster population densities and hence different mean catch rates.

An examination of the average catch rates over all spacings for the eight observations suggests that the locations can be pooled into three groups consisting of low, medium, and high catch rates representing estimates of lobster density (Table 1). Locations with catch rates of less than one lobster per trap are assigned to a low density group, those with 1-2.24 lobsters per trap are assigned to a medium density group, and locations with catch rates of 2.25 lobsters per trap or greater are assigned to a high density group.

Subsequent two-way ANOVA with catch rate per trap as the dependent variable and spacing and location within densities as treatments were performed for the three density levels. Location effects within the low, medium, and high density groups were not significant ($P > 0.10$) whereas spacing effects were significant for the medium density group ($P = 0.004$) but not for the low and high density groups ($P > 0.10$).

Commercial Data

Following the approach used with the Townsend Cromwell data, the average catch rate per trap by location for the commercial data is computed and the locations are partitioned into two groups representing high density and very high density (Table 2). At both densities, there is no difference

between the catch rate between 20- and 30-fathom spacing. For high-density levels, the catch rate at the 10-fathom spacing is significantly lower than the catch rates at the 20- or 30-fathom spacing ($P < 0.05$). The difference between the catch rate at the 10-fathom spacing and the catch rates at the 20- or 30-fathom spacing is not significant at very high-density levels.

CONCLUSIONS

The results from both the Townsend Cromwell and commercial data suggest that gear competition does exist and that it is density dependent. Best catch rates per trap are obtained with spacing between traps in the range of 20 to 25 fathoms for the lobster densities in the Northwestern Hawaiian Islands.

One implication of the spacing and density interaction for researchers is that when estimating relative abundance by catch per unit effort (CPUE), one must be careful to use a large enough spacing to avoid density dependent gear competition. For example, based on the results of Table 2, if 10-fathom spacing were used, the CPUE for high-density levels would be two lobsters per trap and the CPUE for very high-density levels would be about eight lobsters per trap, and we would conclude that very high-density levels have four times the abundance as the high-density levels. However, if 30-fathom spacing were used on the traps, the CPUE for high-density levels would be about 4.4 lobsters per trap and the CPUE for very high-density levels would be 10.4 lobsters per trap, and we would conclude that the abundance at very high-density levels would be only 2.4 times the abundance of high-density levels.

Table 1.--Lobster catch (number) per eight-trap string from Townsend Cromwell cruises.

Replicate	Spacing (fathom) 10	15	20	25	30	Total	Average per trap
I. Low density							
1	3	5	0	0	18	26	0.65
2	11	10	4	1	3	29	0.73
3	1	1	3	4	4	13	0.33
Total	15	16	7	5	[25]		
II. Medium density							
1	9	15	10	23	16	73	1.83
2	23	18	15	18	10	84	2.10
3	15	10	19	16	17	77	1.93
4	19	3	0	34	26	82	2.05
Total	66	46	44	[91] *	69		
III. High density							
1	24	22	35	9	23	113	2.83
2	14	34	31	9	6	94	2.35
3	23	44	38	78	35	218	5.45
Total	61	100	[104]	96	64		

*Spacing effect significant ($P \leq 0.05$)

Table 2.--Mean catch per trap (number of traps) from commercial data.

Replicate	Spacing (fathom) 10	20	30
I. High density			
1	2.40 (N = 17)	--	4.50 (N = 15)
2	2.29 (N = 24)	4.78 (N = 18)	2.46 (N = 27)
3	1.25 (N = 24)	--	5.27 (N = 26)
4	2.37 (N = 25)	--	5.52 (N = 25)
Total	2.06 (N = 90)*	4.78 (N = 18)	4.40 (N = 93)
II. Very high density			
1	7.25 (N = 16)	11.11 (N = 19)	10.18 (N = 11)
2	8.27 (N = 26)	--	10.52 (N = 25)
Total	7.87 (N = 42)	11.11 (N = 19)	10.42 (N = 36)

*Spacing effect significant ($P \leq 0.05$)

Southwest Fisheries Center Administrative Report H-80-15

SEAMOUNT FISHERY, FOREIGN VESSEL OBSERVER REPORT

KITAKAMI MARU (August 9-October 4, 1980)

By

Alan R. Everson
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

November 1980

KITAKAMI MARU

Vessel Statistics

Permit Number:	JA-80-0321A
Length	56.62 m
Gross tonnage:	549.86
Net tonnage:	215.92
Width:	9.20 m
Draft:	4.15 m
Engine type:	Diesel
Horsepower:	1,500
Hull Number:	100765
Registration Number:	TOEN-717
Company/owner:	Nippon Suisan, Ltd.
Vessel type:	Freezer-factory. Independent stern trawler
Year commissioned:	September 1966
Home port:	Konmon-Ko, Tobata, Japan

Personnel

Captain:	Masamichi Ooshio
Number of officers:	8
Number of crew:	22
Galley:	3
Total ship complement:	34
Experience in seamount fishery:	None

The Kitakami Maru was assigned to fish in the U.S. Fishery Conservation Zone (FCZ) on the Hancock Seamounts by Nippon Suisan, Ltd. The vessel left Japan on July 10, 1980 and began fishing at the Colahan and Milwaukee Seamounts. They fished outside the FCZ from July 20 to August 10, 1980. On August 11, they entered the FCZ and picked up the U.S. observer on Midway. Actual fishing in the FCZ began on August 12.

The Kitakami Maru, at 56 m, is probably the smallest trawler in the Nippon Suisan fleet. The company decided to use this vessel largely for economic reasons. It was thought that it would be economical to use the Kitakami Maru at the Hancock Seamounts anticipating small catches inside the FCZ, while the larger Aso Maru would be used to fish the other seamounts outside the FCZ.

The Kitakami Maru fished almost exculsively inside the FCZ from August 12-September 30, 1980. Every 10-14 days, they left the FCZ to offload their catch and to take on fuel and fresh supplies by docking with a cargo vessel that was resupplying vessels in the area. One day was spent fishing outside the FCZ during this period.

Trawl Gear

See Figure 1 for dimensions. The net was modified by replacing two of the center bobbins opposite the cod end with two large cylinder-shaped bobbins composed of hard rubber. This reduced "hangups" by allowing the net to "bounce" over small rocks and ledges.

Area of Operation

1. Outside of the FCZ.

   Colahan Seamount (E bank), lat. 31°01'N, long. 175°52'E

2. FCZ.

   a. Southeast Hancock Seamount (J bank), lat. 29°43'-49'N, long. 179°02'-06'E

   b. Northwest Hancock Seamount (C bank), lat. 30°15'-16'N, long. 178°42'-44'E

   c. K bank, lat 29°40'N, long. 179°20'E

TRAWL RESULTS

Target Species

Common names:	Pelagic armorhead, boarfish
Japanese name:	Kusakari tsubodai
Scientific name:	*Pentaceros richardsoni*
Species code:	080

Common name:	Alfonsin
Japanese name:	Kinmedai
Scientific name:	*Beryx splendens*
Species code:	081

The general fishing strategy involved surveying the seamount area prior to setting the net each time a new area was fished. Fish concentrations on the seamounts were determined through the use of two Sanken fish finders. At this time, the direction and location of the tow on the seamount were determined and the ship was brought into position for the first pass. The net was lowered to the proper depth just prior to contact with the seamount. After contact, the net recorder was monitored to determine the density of fish entering the net and also to watch for "hangups." Trawling was conducted on the bottom, the cod end actually riding about 1 m off the bottom. Upon reaching the end of the seamount, the vessel retrieved the trawl doors, made a 90° turn, lowered the doors, and net, and resumed fishing. Several passes were often made before the net was hauled aboard ship. This was done to save fishing time, since the amount of fish caught on one pass was usually small. In calculating the catch per unit effort (CPUE), the fact that total trawling time is not the actual time on the bottom must be taken into consideration. Trawling time can be considered total

time per haul the net was in the water between the period of contact with the bottom on the first pass, and the time the net left the bottom on the last pass. At Southeast Hancock Seamount, this time averaged 97.4 minutes per haul for 110 hauls. The 61 hauls at Northwest Hancock Seamount averaged 85.4 minutes per haul. The two hauls on K bank averaged 10 minutes per haul.

Outside the FCZ at Colahan Seamount, the four hauls averaged 115 minutes per haul. Of the 704.6 metric tons (MT) caught inside the FCZ between August 12-September 30, 1980, 654.0 MT or 93% consisted of pelagic armorhead. There were 31.7 MT of alfonsin caught, 4% of the total. Other species made up 3% of the catch or 18.9 MT.

During the survey, 41 out of 42 fishing days were spent inside the FCZ. One day was spent at Colahan Seamount. The catch consisted of 5.9 pelagic armorhead, 2 MT alfonsin, and 2 MT other species.

The largest single catch was at Northwest Hancock Seamount and consisted of 20.0 MT, 19 MT of which was pelagic armorhead. Out of 173 hauls inside the FCZ, 57 were greater than or equal to 5.0 MT. There were six zero hauls, four of these resulting from net "hangups." The average catch per haul was 4.1 MT. In the FCZ, 80% of the armorhead and 66% of the alfonsin were caught between 1800-0600 hours. The percentage of fish caught during these hours increased during the fishing season. During the last 2 weeks of fishing, 90% of the fish were caught between these hours.

SAMPLING RESULTS

1. Pelagic armorhead, Pentaceros richardsoni.

Morphology (hauls 1-69). Samples from hauls 1-69 were divided into two types of pelagic armorhead, fat and lean. These two body types may have significant genetic differences so they were recorded separately.

a. Southeast Hancock Seamount.

Lean type 57%

Number measured: 1,841

Sex ratio:	Male	439	(55%)
	Female	359	(45%)

Average length: 295 mm Range: 255-337 mm
Average weight: 0.48 kg

Fat type: 43%

Number measured: 1,372

Sex ratio: Male 239 (45%)
Female 292 (55%)

Average length: 308 mm Range: 287-344 mm
Average weight: 0.63 kg

b. Northwest Hancock Seamount

Lean type: 73%

Number measured: 627

Sex ratio: Male 226 (57%)
Female 168 (43%)

Average length: 295 mm Range: 261-335 mm
Average weight: 0.44 kg

Fat type: 27%

Number measured: 233

Sex ratio: Male 65 (52%)
Female 61 (48%)

Average length: 307 mm Range: 270-325 mm
Average weight: 0.63 kg

Morphology (hauls 70-167). After haul 70, it became increasingly more difficult to divide the armorhead into the two body types. A third intermediate body type became more prevalent. Because of this, samples from hauls 70-167 were divided into three body types: fat, lean, and medium.

a. Southeast Hancock Seamount

Lean type: 27%

Number measured: 378

Sex ratio: Male 166 (76%)
Female 53 (24%)

Average length: 292 mm Range: 258-323 mm
Average weight: 0.42 kg

Fat type: 16%

Number measured: 230

Sex ratio: Male 78 (51%)
Female 75 (49%)

Average length: 314 mm Range: 288-334 mm
Average weight: 0.67 kg

Medium type: 57%

Number measured: 805

Sex ratio: Male 302 (65%)
Female 162 (35%)

Average length: 304 mm Range: 280-326 mm
Average weight: 0.57 kg

b. Northwest Hancock Seamount

Lean type: 48%

Number measured: 320

Sex ratio: Male 197 (62%)
Female 121 (38%)

Average length: 292 mm Range: 261-342 mm
Average weight: 0.41 kg

Fat type: 8%

Number measured: 54

Sex ratio: Male 26 (59%)
Female 18 (41%)

Average length: 312 mm Range: 295-331 mm
Average weight: 0.68 kg

Medium type: 44%

Number measured: 292

Sex ratio: Male 162 (67%)
Female 79 (33%)

Average length: 306 mm Range: 275-334 mm
Average weight: 0.59 kg

2. Alfonsin

Morphology. Alfonsins made up a relatively small part of the total catch inside the FCZ. Of the 31.8 MT caught, approximately 50% could not be utilized commercially because of their small size. Although the other species of alfonsin, Beryx decadactylus, made up less than 1% of the total alfonsin caught, their incidence increased significantly during the last few days of fishing.

a. Southeast Hancock Seamount

Number measured: 907

Sex ratio:	Male	41 (54%)	
	Female	35 (46%)	
Average length:		217 mm	Range: 152-358 mm
Average weight:		0.22 kg	

b. Northwest Hancock Seamount

Number measured: 523

Sex ratio:	Male	49 (53%)	
	Female	44 (47%)	
Average length:		229 mm	Range: 161-358 mm
Average weight:		0.31 kg	

Ninety percent of the alfonsin sampled were less than 200 mm in length. At this size, they are often sexually immature. Therefore, the sex ratio reflects only a small percentage of the total sample.

3. Other commercial species

The only other species that was utilized as a commercial product in significant quantities was Hyperoglyphe japonica. Often 25-30 large (5-10 kg) individuals were caught in an average haul. Another species caught in large quantities was Erythocles schlegelii. These were not utilized as a commercial product.

4. Coral

No precious coral was uprooted inside or outside of the FCZ.

SHIPBOARD PRODUCTS (HANCOCK SEAMOUNTS)

Species Product

1. Pelagic armorhead

Frozen fish (headed and gutted)	385.6 MT
Fish meal and oil	0

The body of pelagic armorhead ranged from 56-60% of total weight after machine processing.

2. Alfonsin

Frozen whole or headed and gutted	9.5 MT
Fish meal and oil	0

3. Other species

Frozen whole or filleted	5.1 MT
Fish meal and oil	0

By Products

The Kitakami Maru did not have a fish meal factory. All of the waste products were discarded. In addition, about 50% of the total alfonsin and all of the other species not used as commercial products were discarded. Alfonsin were usually too small in size or sustained too much damage during the long hauls to be used as commercial products. A rough estimate of 40-50 MT of whole fish (alfonsin and other species) were simply thrown overboard.

ITINERARY

August	9	- Departed Honolulu, Hawaii Arrived Midway
	11	- Embarked Kitakami Maru
	12	- Began sampling
September	24	- Transferred to Aso Maru Began sampling
	30	- Transferred back to Kitakami Maru
October	2	- Arrived Midway
	4	- Arrived Honolulu

NOTE: After my transfer to the Aso Maru, observer Gordon Tribble was picked up on Midway by the Kitakami Maru. He remained on board during the period of September 27-30. The 2 days that Mr. Tribble sampled aboard the Kitakami Maru have been incorporated into these results.

RECORDS

The following records were kept:

Scientists Log
Daily Trawl Haul Form
Species Composition From Basket Samples
Size-Frequency Log

OBSERVERS: Alan R. Everson, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, Hawaii 96812, August 9-September 24, 1980

Gordon W. Tribble, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, Hawaii 96812, September 26-October 4, 1980.

Table 1.--Trawl catches by species and area (in metric tons).

Species	Fishery Conservation Zone	Outside
Armorhead	654.0	5.9
Alfonsin	31.7	0.2
Others (listed below)	18.9	0.2
Erythrocles schlegelii		*Grammatonotus laysanus*
Hyperoglyphe japonica		*Promethichthys prometheus*
Polymixia japonica		*Etmopterus villosus*
Zenopsis nebulosa		Myctophidae spp.
Antigonia eos		Oncocephalidae spp.
Scomber japonicus		Sternoptychidae sp.
Macrorhamphosus gracilus		*Stethopristes eos*
Laemonema rhodochir		*Hoplostethus mediterraneous*
Decapterus russelli		Lepidopidae sp.
Ariomma lurida		*Prionace glauca*
Chascanopsetta prorigera		*Parabothus coarctatus*
Ruvettus pretiosus		*Beryx decadactylus*
Squalus blainvillei		*Priacanthus boops*
Alopiidae sp.		*Hexanchus grisens*
Scorpaenidae sp.		
Total	704.6	6.3

Note: Checklist incomplete pending further identification of specimens.

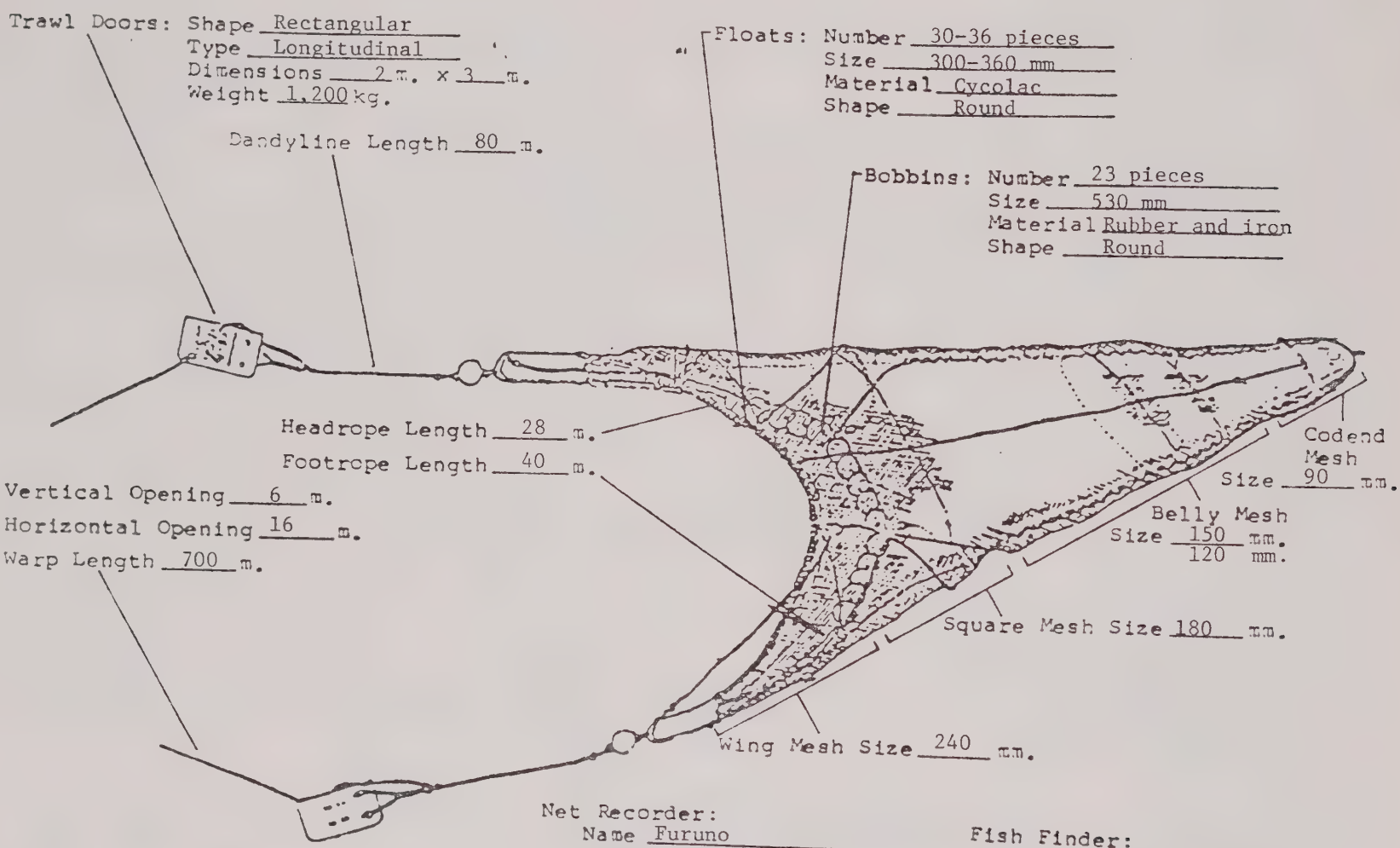
Table 2.--Catch-per-unit-effort by species and area.

Area	No. hauls	Total minutes (trawl in water)	Armorhead		Alfonsin		Other species		All species	
			Total catch (kg)	Kg/min	Total catch (kg)	Kg/min	Total catch (kg)	Kg/min	Total catch (kg)	Kg/min
Southeast Hancock Seamount	102	9,650	461,100	47.78	23,700	2.46	14,100	1.46	498,900	51.70
Northwest Hancock Seamount	59	5,050	192,900	38.20	7,800	1.54	4,600	0.96	205,300	40.65
K Bank	2	10	0	--	200	20.0	200	20.0	400	40.0
Colahan	4	460	5,900	12.83	200	0.43	200	0.43	6,300	13.70
			659,900		31,900		19,100		710,900	

NET DIMENSIONS AND CHARACTERISTICS

Type of Vessel Stern trawler

Observation Period August 11-September 30, 1980



Net Recorder:
Name Furuno
Model Number 1330323
Frequency 60 Khz

Fish Finder:
Nate Raijyo-Denki
Model Number 1802
Frequency 60 Khz
Paper Type - Wet X Dry
Speed of Advance 12 mm/min

Figure 1.--Kitakami Maru

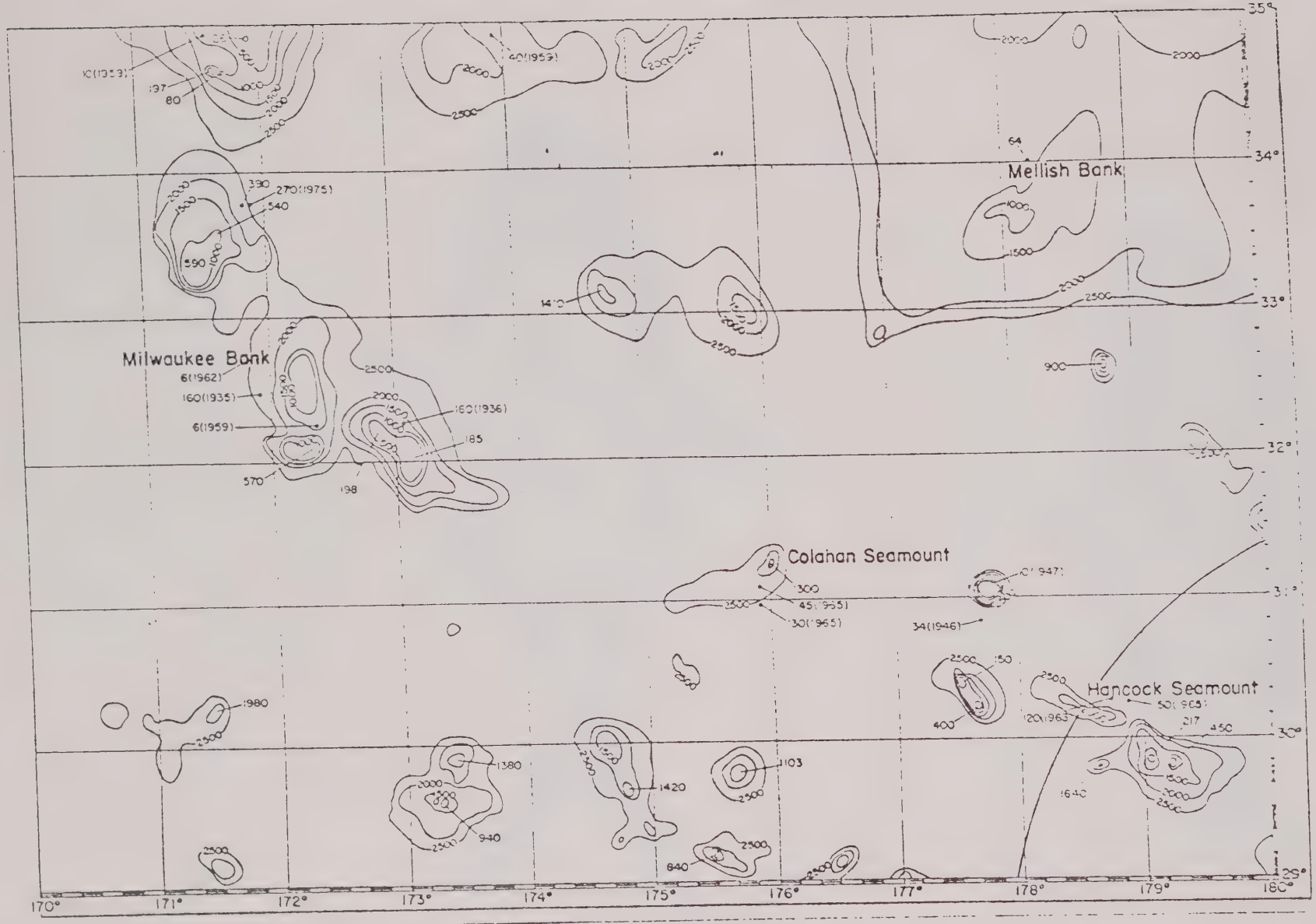
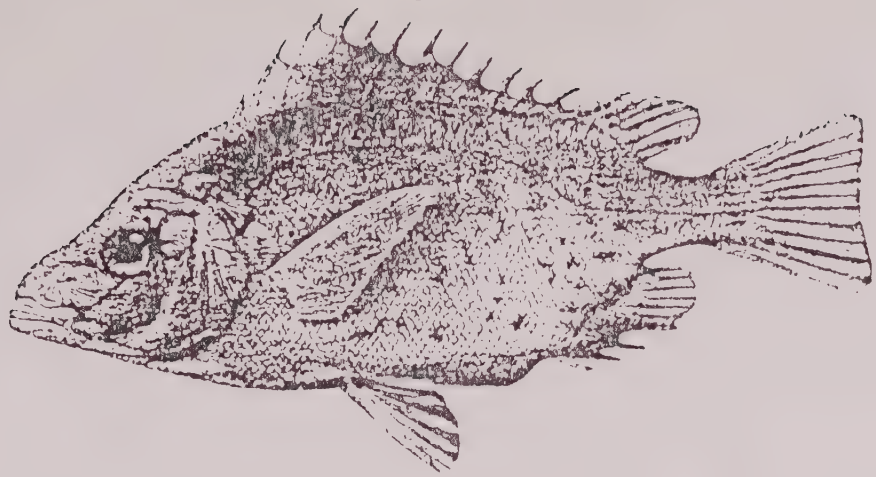
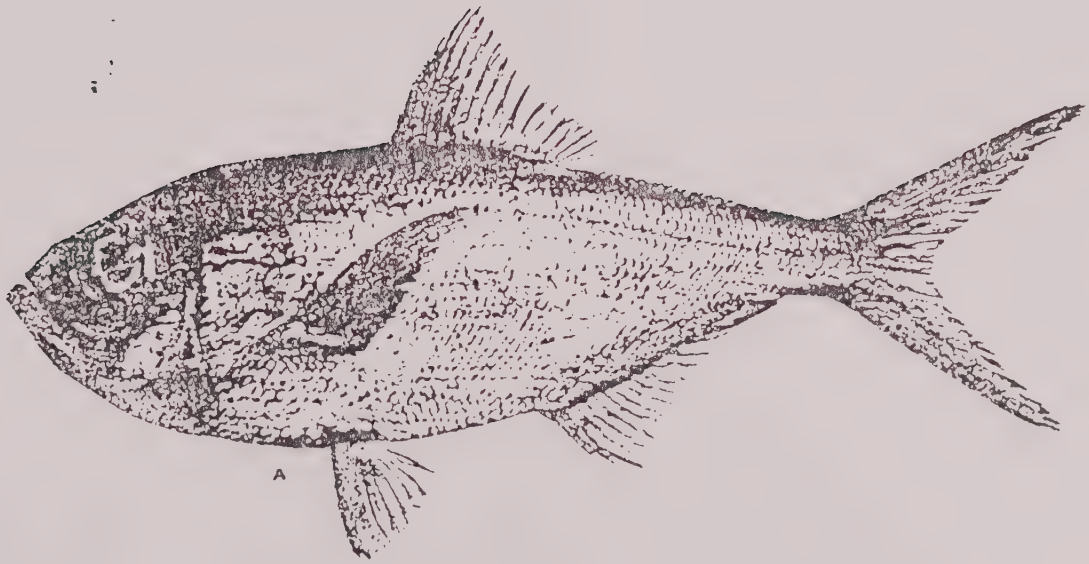


Figure 2.--Locations of seamounts and guyots northwest of the Northwestern Hawaiian Islands. Year of discovery is indicated for each guyot, and the 200-mile line is shown. Depths in fathoms.



Pelagic armorhead (Pentaceros richardsoni)



Alfonsin (Beryx splendens)

Figure 3.--Illustrations of adult armorhead and alfonsin.

80-16

SEAMOUNT FISHERY, FOREIGN VESSEL OBSERVER REPORT

ASO MARU (September 24-30, 1980)

By

Alan R. Everson
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

NOV 17 1980

November 1980

ASO MARU

Vessel Statistics

Permit Number:	JA-80-0288A
Length:	90.45 m
Gross tonnage:	3,608.29
Net tonnage:	1,968.1
Width:	16.0 m
Draft:	5-6 m
Engine type:	Diesel
Horsepower:	3,900
Hull Number:	96090
Registration Number:	TOEN-701
Company-owner:	Nippon Suisan, Ltd.
Vessel type:	Independent stern trawler
Year commissioned:	1964
Home port:	Tobata, Japan

Personnel

Captain:	Kiyomi Kinoshita
Number of officers:	9
Number of crew:	26
Galley and steward:	8
Processing:	19
Total ship complement:	54*
Experience in seamount fishery:	Captain - 4 seasons Chief Officer - 3 seasons

Area of Operation

Seamounts	Latitude	Longitude
Kinmei	35°00'N	171°45'E
Milwaukee seamount group:		
Yuryaku	32°40'N	172°15'E
Kanmu	32°10'N	173°00'E
Colahan	31°15'N	176°00'E
Fishery Conservation Zone:		
Northwest Hancock	30°15'-16'N	178°42'-44'E
Southeast Hancock	29°43'-49'N	179°02'-06'E
K Bank	29°40'N	179°20'E

*Crew members have varied duties consequently the total ship's complement is less.

TRAWL RESULTS

Target Species

Common names:	Armorhead, boarfish
Japanese name:	Kusakari Tsubodai
Scientific name:	Pentaceros richardsoni
Species code:	080

Common name:	Alfonsin
Japanese name:	Kinmedai
Scientific name:	Beryx splendens
Species code:	081

The Aso Maru was assigned to fish the seamounts outside the U.S. Fishery Conservation Zone (FCZ) from Colahan to Milwaukee Bank. They fished from April 29 through September 23, 1980. On September 24, due to the poor catches made outside the FCZ, they decided to enter the FCZ and fish at the Hancock Seamounts. At this time, I was transferred from the Kitakami Maru to the Aso Maru. The Kitakami Maru then proceeded to Midway Islands to pick up another National Marine Fisheries Service (NMFS) observer. The Aso Maru operated inside the FCZ until September 30. I was then retransferred to the Kitakami Maru and disembarked at Midway Islands along with the other observer. Both ships left the FCZ and returned to Japan.

The Aso Maru is a large factory trawler, with a complete fish meal and oil factory.

Trawl Gear

See Figure 1 for dimensions.

Twenty hauls were made on the Northwest Hancock Seamount averaging 96 minutes per haul. The 14 hauls at Southeast Hancock Seamount averaged 156 minutes per haul.

Out of a total of 90.8 metric tons (MT) caught in the FCZ from September 24-30, 80.7 MT or 89% consisted of armorhead, 2.6 MT or 3% of alfonsin, and 7.5 MT or 8% of other species.

SAMPLING RESULTS

1. Pelagic armorhead, Pentaceros richardsoni

   Morphology. The armorheads were divided into three body types: fat, lean, and medium, These may be genetically different so they were recorded separately.

a. Southeast Hancock Seamount

Lean type 35%

Number measured: 130

Sex ratio: Male 67 (63%)
Female 39 (37%)

Average length: 291 mm Range: 264-321 mm
Average weight: 0.40 kg

Fat type 13%

Number measured: 47

Sex ratio: Male 15 (54%)
Female 13 (46%)

Average length: 312 mm Range: 298-331 mm
Average weight: 0.68 kg

Medium type 52%

Number measured: 195

Sex ratio: Male 69 (62%)
Female 42 (38%)

Average length: 305 mm Range: 279-327 mm
Average weight: 0.59 kg

b. Northwest Hancock Seamount

Lean type 45%

Number measured: 108

Sex ratio: Male 71 (66%)
Female 36 (34%)

Average length: 291 mm Range: 257-316 mm
Average weight: 0.42 kg

Fat type 11%

Number measured: 27

Sex ratio: Male 10 (37%)
Female 17 (63%)

Average length: 314 mm Range: 299-327 mm
Average weight: 0.70 kg

Medium type 43%

Number measured: 103

Sex ratio: Male 35 (35%)
Female 65 (65%)

Average length: 306 mm Range: 290-327 mm
Average weight: 0.59 kg

2. Alfonsin

Morphology. Enough alfonsin could not be sampled to yield reliable results. The average weight of the 22 alfonsin sampled on both Northwest and Southeast Hancock Seamounts was 0.54 kg. The average length for these was 276 mm.

3. Other commercial species

The most common "other" species that was caught and used as a product was Hyperoglyphe japonica.

4. Coral

About 1.0 kg of bamboo coral, Keratoisis nuda, was uprotted in the FCZ at Northwest Hancock Seamount and immediately thrown overboard.

SHIPBOARD PRODUCES (HANCOCK SEAMOUNTS)

Species Product

1. Armorhead

Frozen fish (headed and gutted)	48 MT
Fish meal and oil	__ MT[1]

The recovery ratio is estimated to be about 56-60% of the total weight after machine processing.

2. Alfonsin

Frozen whole or headed and gutted	1 MT
Fish meal and oil	__ MT[1]

3. Other species

Frozen whole or filleted	1 MT
Fish meal and oil	__ MT[1]

[1]Not able to obtain data.

By Products

All waste material (head, viscera) and species not utilized as a frozen product were converted into fish meal and oil.

ITINERARY

September	24	- Debarked Kitakami Maru Embarked Aso Maru
	30	- Sampling ended Debarked Aso Maru Embarked Kitakami Maru
October	2	- Arrived Midway
	4	- Arrived Honolulu

RECORDS

The following records were kept:

Scientists Log
Daily Trawl Haul Form
Species Composition From Basket Samples
Size-Frequency Log

OBSERVER: Alan R. Everson, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, Hawaii 96812, September 24-October 4, 1980.

Table 1.--Trawl catch by species and area (in metric tons).

Species	Fishery Conservation Zone	Outside
Armorhead	80.7	863.5
Alfonsin	2.6	5,660.6
Others	7.5	188.8
Total	90.8	6,712.9

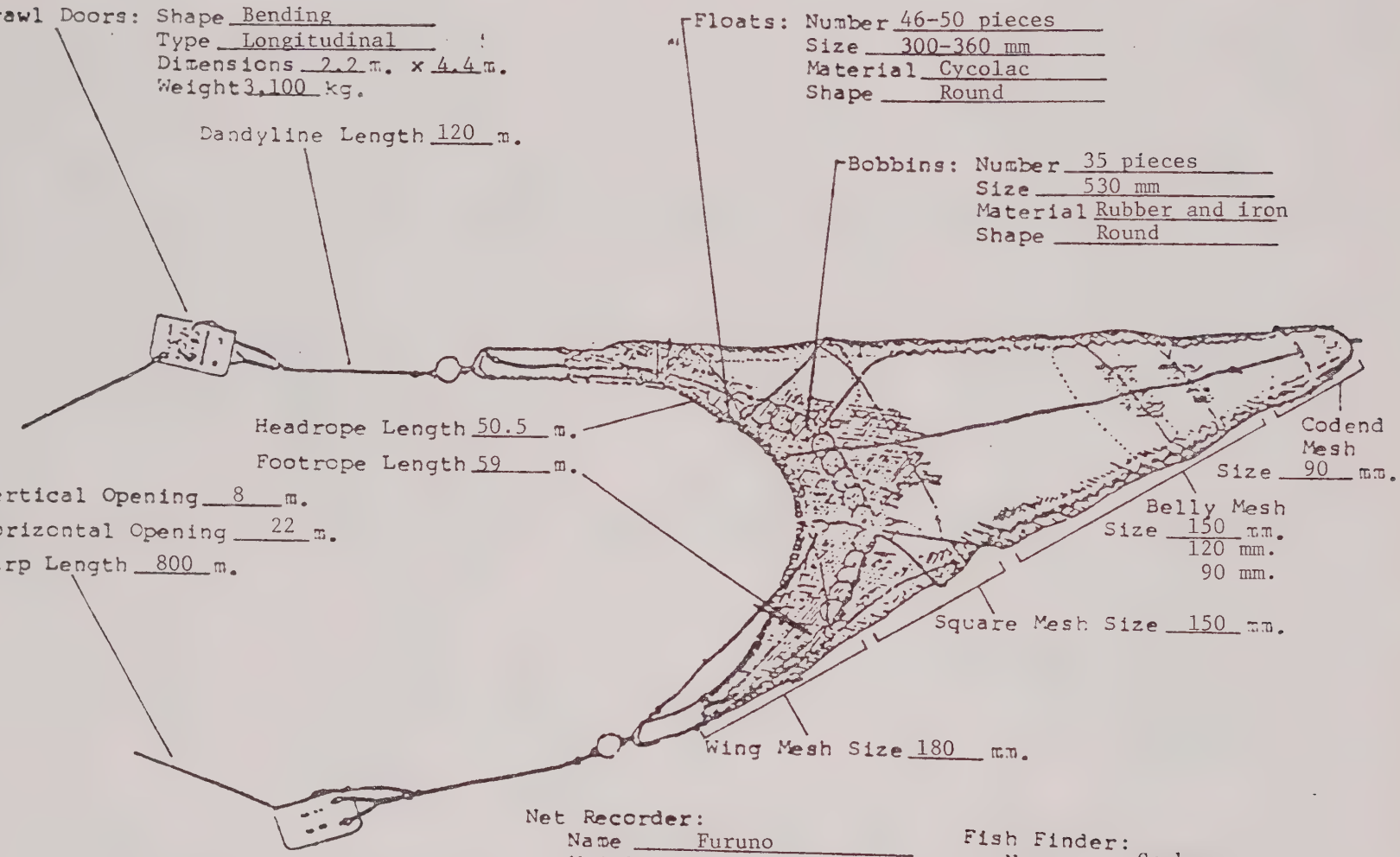
Table 2.--Catch-per-unit-effort by species and area.

Area	No. hauls	Total minutes (trawl in water)	Armorhead		Alfonsin		Other species		All species	
			Total catch (kg)	Kg/min	Total catch (kg)	Kg/min	Total catch (kg)	Kg/min	Total catch (kg)	Kg/min
Southeast Hancock Seamount	14	2,190	40,500	18.49	900	0.42	4,000	1.83	45,400	20.73
Northwest Hancock Seamount	20	1,925	40,200	20.88	1,600	0.83	3,300	1.71	45,100	23.43

NET DIMENSIONS AND CHARACTERISTICS

Type of Vessel Stern trawler

Observation Period September 24-30, 1980



Net Recorder:
Name Furuno
Model Number FNR-50
Frequency 50 Khz

Fish Finder:
Name Sanken
Model Number WSV2-16
Frequency 50 Khz
Paper Type - Wet 0 Dry
Speed of Advance 14 mm/min

Figure 1.--Aso Maru.

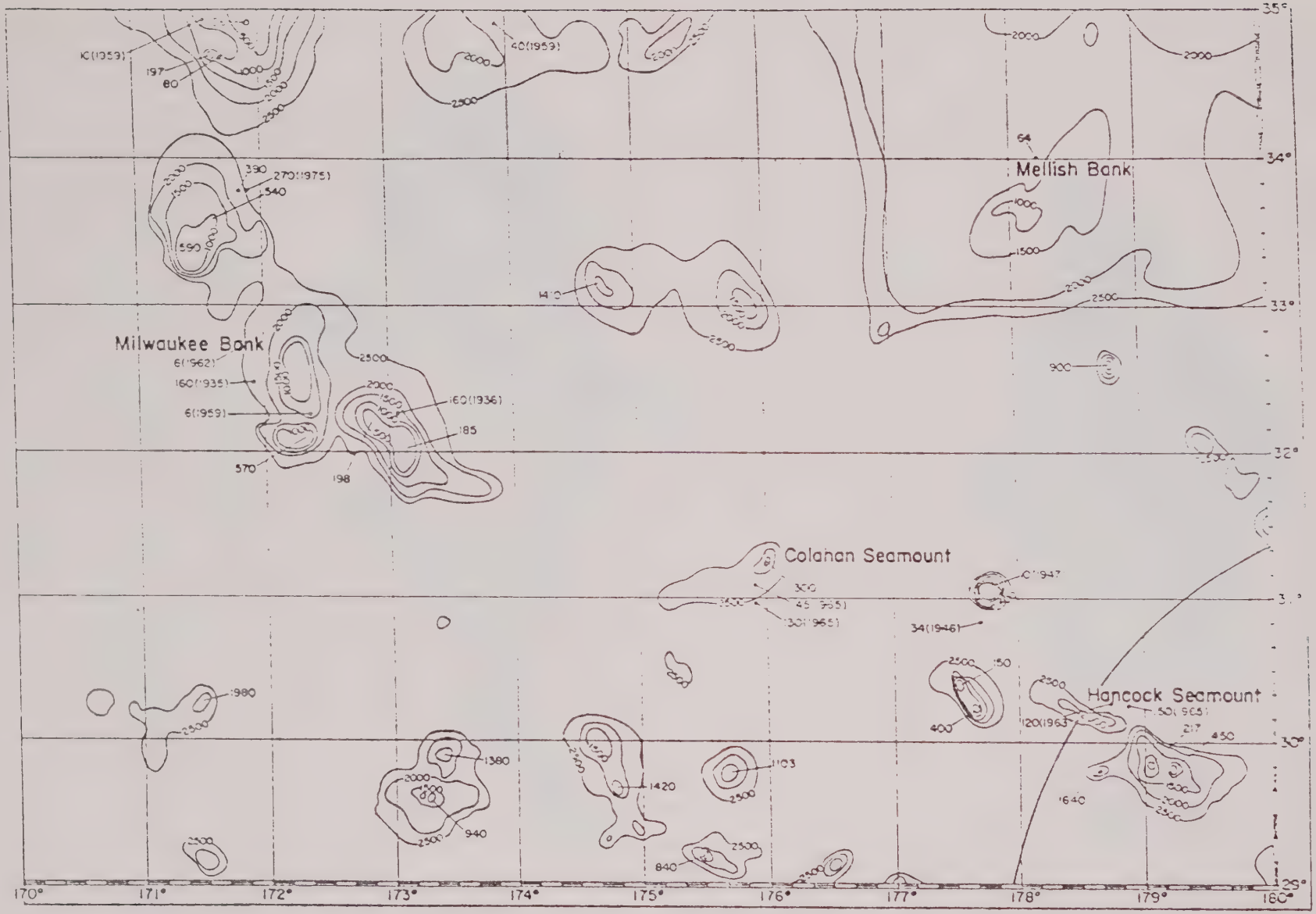
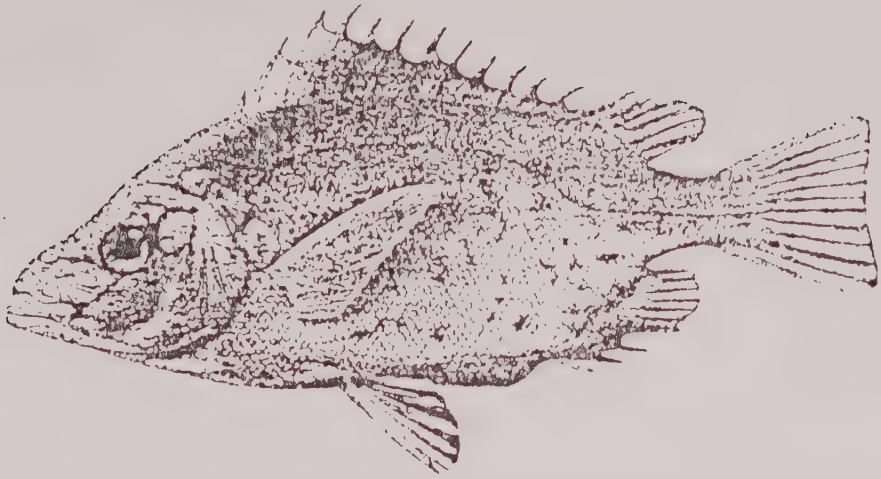
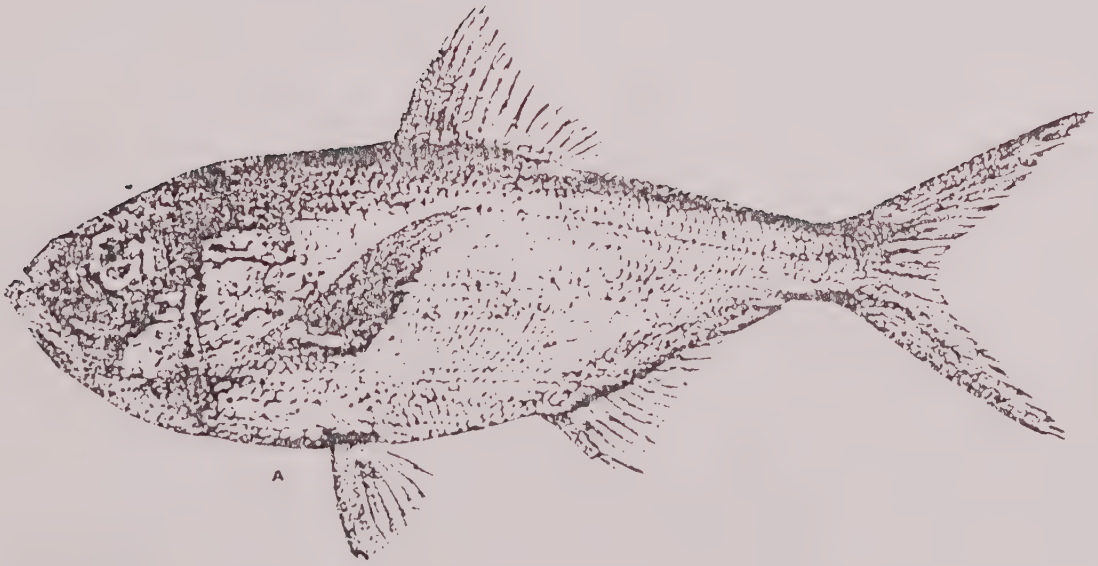


Figure 2.--Locations of seamounts and guyots northwest of the Northwestern Hawaiian Islands. Year of discovery is indicated for each guyot, and the 200-mile line is shown. Depths in fathoms.



Pelagic armorhead (Pentaceros richardsoni)



Alfonsin (Beryx splendens)

Figure 3.--Illustrations of adult armorhead and alfonsin.

Southwest Fisheries Center Administrative Report H-80-17C

"Living Tags" For Sea Turtles

Report to SW Fisheries Center

National Marine Fisheries Service

Honolulu, Hawaii

Contract #80-ABH-00062

DEC 30 1980

J. R. Hendrickson

Lupe P. Hendrickson
4917 N. Camino Arenosa
Tucson, Arizona 85718

October 15, 1980

Since this report has been prepared under contract, the statements, findings, conclusions, and recommendations herein are those of the contractors and do not necessarily reflect the view of the National Marine Fisheries Service.

Tamio Otsu
Acting Director, Honolulu Laboratory
Southwest Fisheries Center
National Marine Fisheries Service

"Living Tags" For Sea Turtles

by

J. R. Hendrickson and Lupe P. Hendrickson

Introduction

This report describes work carried out under NMFS Contract No. 80-ABH-00062 in Honolulu, Hawaii during the period 9 September to 15 October 1980. The work, with hatchlings of the green sea turtle (Chelonia mydas), was authorized under U.S. Fish & Wildlife Service Sea Turtle Permit No. PRT2-6842 and was done under the supervision of Technical Monitor William Gilmartin who made the basic decisions on types of treatments, numbers of animals in each treatment group, and times when the Contractors performed the operations. Maintenance regimens are determined by NMFS under a separate contract with Sea Life Park where the subject animals were established and where they will be held for a post-operative year of monitoring. Aside from the post-operative inspections by the Contractors, reported here, all monitoring will be handled by NMFS staff. By agreement, this present paper constitutes the final written report on Contract No. 80-ABH-00062.

Starting date on this contract was delayed beyond the proposed date of 1 September 1980 because the first group of animals was not available until September 8.

Background Information

For the past 30 years, the present Contractors and other students of sea turtle ecology have been unable to develop a clear understanding of many aspects of the life history of these animals because of our inability to mark the 20-30 g hatchlings so that they can be identified years later when they may weigh as much as 100 kg.

Almost every conceivable device and method has been tried. No ordinary, externally applied tag or band can meet the need because of the long span of time and the animals' enormous change in body mass. Mutilation markings do not serve because of variable healing, regeneration, and replication by natural accidents. Hughes (1975) notched the shells of 17,000 baby loggerhead sea turtles and reported 6 "probable" returns; Bustard (1979) reports a single positive return from 65,000 green sea turtle hatchlings marked in a massive program. Tattooing is soon absorbed or obscured. Branding by either heat or freezing is unsatisfactory because wound-healing processes stimulate melanocyte re-invasion and growth obscures the branding sites. Magnet implants did not work for Carr (1967). Radioactive tagging methods have not proved to be practical. Injection of rare metals for later detection by neutron activation analysis has been tested (Forbes 1972), but has little practical promise. One of the present investigators worked with immunologists (See Benedict and Pollard 1972) exploring, without success, the possibility of developing

an immunological "living tag" analogous to the long-lived smallpox immune bodies induced in humans by vaccination. We remain about where we started, with no direct approach to the problem.

The prime requirement of the needed marking system is that it endure over a long period, remaining clearly visible and accurately identifiable under field conditions despite great increases in animal body size. Obviously, the mark must also have minimal unfavorable effect on the behavior, mobility, dispersal, health, and other elements of the life history of the marked individual (Plummer 1979, Delaney 1978).

Some of the most important remaining gaps in our understanding of sea turtle biology, potentially resolvable given the existence of an efficient method of lifetime tagging and critically important to decision-makers in conservation management programs, are the following:

1) We are unable to test the hypothesis that sea turtles "imprint" on their natal beach and return there to nest as adults. This has much bearing on national policies toward native turtle populations, etc.

2) We have no direct means for determining the distributions of subadult populations relative to their beaches of origin.

3) We have almost no "hard" quantitative data on growth rates or maturation times in the wild--a basic need for evaluation of assets.

4) We cannot, at present, gauge the success of otherwise-promising "headstart" programs, now being carried out,

intended to reduce juvenile mortality and augment natural recruitment rates.

Much of what we do know about turtle behavior and movements in the sea has been derived from the chance retention of metal tags which have a high, variable, and unpredictable rate of loss (Green 1979). The total expenditure in time, labor, and dollars for each datum obtained is very high; efforts must be made to reduce unit costs and increase information retrieval. If proven usable, the "living tag" approach should go far toward improving this situation.

Materials and Methods

All work described here was done at Sea Life Park, Makapuu, Oahu, Hawaii. The hatchlings are presently installed in six holding tanks measuring 72 in x 22 in, and a circular tank measuring 72 inches in diameter. They are kept in no more than 8 in of water (4-8 in) to insure that they are able to see and reach the food at the bottom of the tanks.

Fifty-three hatchlings were brought to Honolulu on 8 September. The group consisted of one clutch of identifiable siblings (hatched on 6 September 1980), plus a larger number of animals salvaged by digging into recent emergence sites for individuals which had failed to reach the surface with the main body of their siblings. This larger group of culls came from nests which the field party considered to have hatched during 5, 6, and 7 September. For purposes of age notation in this report, all are considered to have begun life

on the surface on 6 September 1980. Because many of the animals appeared weak and unlikely to survive, it was decided to postpone initiation of experimental work for about one week in order to allow them a period of stabilization.

A second shipment of 182 hatchlings arrived on 19 September. This group consisted of 110 siblings that emerged on the night of 18 September from a marked nest laid by tagged, wild female #200, and 72 siblings from an unmarked nest which was discovered while the young were emerging (also on 18 September). On their first night in Honolulu, the tank holding the clutch of 110 siblings overflowed; one hatchling drowned in the tank drain, and 14 others were washed out with the overflow. Two of the 14 were never recovered; the 12 recovered individuals were inadvertently placed with the smaller group of siblings from the unmarked nest. This second shipment of animals, in contrast to the first, appeared to be normally active and robust. The first grafts on these were done four days after their arrival.

Numbered metal tags (National Band and Tag Co. Monel metal tags, series #1005, size 1) were affixed to the last, right marginal scute of all experimental animals. The animals were divided into three treatment groups and one tagged-control group. Sixty-three animals were reserved as controls; 59 were given reversed-plug grafts; 50 were given disk grafts, and 50 were given gouge grafts (see below). All graft wounds were treated with Neosporin (an antibiotic ointment produced by Burrows Wellcome Co., N. Carolina) before

the animals were returned to the water. A "register" (Appendix I) is attached to this report and presents, in tabular form, details of treatment for each individual animal and dates of mortalities through 15 October 1980.

Tagged controls. At the start of the grafting work, on 17 and 18 September, 13 animals from the first shipment were designated as controls. These were not randomly selected, but were those animals left after selection of the 30 most vigorous individuals for treatment.[1] The 50 controls from the second shipment were randomly selected, as were all of the animals from this shipment, whatever their treatment designation.

Reversed-plug grafts. A cutter (2 mm internal diameter) from an ordinary leather punch was machined to a reduced wall thickness so as to create as straight-walled a cylinder as possible. The cutting edge was finely honed and the cutter was mounted in a handle made from a short length of slender PVC pipe. In performing the grafting operation, the animal was held upside down, with the dorsal surface of the scute to be cut resting on a firm cutting surface. The cylindrical cutter was then used to cut a plug of tissue from that scute by holding the cutter approximately perpendicular to the ventral surface of the scute while rotating it back and forth through an arc of about 180°. Care was always taken not to

1. Procedure requested by NMFS Technical Monitor.

apply a crushing pressure on the tissues, but to use only enough driving force to cause the sharp cutting edge to excise a cleanly cut plug. The plug was then reversed dorsoventrally and reinserted into its own hole. Some of the animals received double grafts; i.e., a second plug was cut out of the same scute and reinserted as described. A number of the second plugs were cut immediately after the first, which was thereby pushed farther into the cylinder, both ending up encased within the cutter with the first plug on top of the second. Both were removed without difficulty by demounting the cutter from the PVC handle and pushing against the first plug with a blunted hypodermic needle. In turn, each was removed, reversed, and inserted into its own hole. The grafts were then sealed with a fast-drying cyanoacrylate surgical adhesive and treated with antibiotic ointment.

All but two reversed-plug grafts were made on the last, left marginal scute. Animal #47 was grafted on the penultimate, left marginal scute because the last marginal scute was too small to take the two grafts done on this animal. Animal #124 was mistakenly grafted on the penultimate, left marginal scute. All of the 30 animals experimentally treated from the first shipment were given reversed-plug grafts--15 single and 15 double grafts. Of these, eight of the double, and seven of the single, grafts were sealed with Permabond (Polysciences, Inc., Warrington, PA), a veterinary surgical adhesive. Seven double, and eight single grafts were sealed with Histoacryl blau, a cyanoacrylate adhesive made by B.

Braun Melsungen, W. Germany, for use in human, internal surgery but not yet approved for use in this country. It was thought that this was a good opportunity to test the relative effectiveness of the two adhesives because, whereas Histoacryl blau had been used before and found effective by the Contractors, Permabond is much cheaper and more readily accessible in this country.

Twenty-nine hatchlings from the second shipment were given reversed-plug grafts on 30 September 1980. Of these, 15 received single grafts and 14 received doubles. All of these were sealed with Permabond. (See register for details of treatment given each individual animal.)

Disk grafts. A 3 mm diameter Keyes dermal punch (K/S Instrument Corp., Clifton, NJ #46003 0), held perpendicular to the keratin surface, was rotated to cut a circle through to the subdermal tissue at a selected site on the plastron. The animal was then inverted in the operator's hand and a similar circle was cut in the carapace at the site selected for grafting. The carapace disk was cut free using a small scalpel (Bard-Parker 15C or 15), set aside for later use, and the plastral disk was then similarly cut free and immediately transferred to the prepared site on the carapace. After firm pressure was applied on the scion with the pad of a finger, or using an absorbing tissue if there was fluid to be cleared, the graft seam was sealed with a cyanoacrylate adhesive (see register). The disk removed from the carapace was then placed

in the plastral wound and the seam was sealed in the same manner as for the dorsal graft.

Graft site (carapace) and scion site (plastron) selection was based on the hypothesis that scute growth occurs mainly, if not entirely, at the seams. Therefore, scions were taken from a single scute from an area tangential to a seam, or from two scutes across a common seam. Consideration was also given to selecting a donor site, on the plastron, where the application of vertical pressure on delicate internal organs could be avoided, guarding against causing undue compression that might be damaging. For the most part, the lateral plane of the second left plastral scute was used. On the carapace the graft was generally placed across the seam between right costal scutes 1 and 2, or within right costal scute 2 at a site tangent to its seam with right costal scute 1 (see register). All disk grafts were done on 23 September 1980.

Gouge grafts. A 5 mm diameter Keyes dermal punch (K/S Instrument Corp., Clifton, NJ #46005 5) was employed with an angular orientation instead of perpendicular to the keratin surface as in making disk grafts. A gouge was cut from the carapace by rotating the punch in alternating arcs of approximately 90° while applying sufficient forward force to slice through the tissue. The wound was then filled with a similar gouge of tissue cut from the plastron in the same manner. The same considerations in selecting dorsal and ventral treatment sites apply as discussed under "Disk grafts." On 18 of the animals treated with this type of graft, the plastral wound

was covered with surgical adhesive only. This was done to compare healing rates of wounds covered with the animal's tissue and those sealed only with adhesive (see register). All gouge grafts were done on 24 September 1980.

Post-operative inspections. The Contractors made two post-operative checks, at which time they examined each animal individually. The first check, on 30 September, was on the 12th- and 13th-day post-operative for the 30 animals with reversed-plug grafts from the first shipment, and the 6th- and 7th-day post-operative for the gouge and disk graft groups respectively. At this time the last 29 reversed-plug grafts were also done, and the 50 controls from the second shipment were designated. The second check was done on 15 October 1980.

Results and Discussion

Effects of grafting on survivorship. A major concern in this work was the question of whether or not the grafting operations would affect survival in the young turtles. For purposes of the experiment, it was assumed that significant ill effects from grafting (deaths, apparent general morbidity, infection foci at graft sites, and biting damage near the contrastingly shaded grafts) would be detectable by comparison with the 63 control animals. These controls included representation from both shipments and they were distributed through all the holding tanks during post-operative maintenance. Because of the different histories of the two shipments from French Frigate Shoals, we will consider them separately.

As explained previously, the first shipment included a number of obviously disadvantaged animals. Ten individuals died between the time of arrival in Honolulu and the beginning of our work on 17 September. By 15 October (27th/28th day post-operative), nine more animals had died--5 of 30 (16.7%) reversed-plug grafted animals and 4 of 13 (31%) tagged controls.[2] None of the survivors were noted as being particularly emaciated or showing other signs of morbidity. Almost all (both grafted and control individuals) showed some degree of biting damage on the tail and trailing edges of the flippers, but there was no apparent correlation of biting damage with graft sites. There were no conspicuous fungal infections on shell or skin.

Five of the animals from the second shipment had also died at the time of the second post-operative inspection on 15 October (15 to 23 days post operative).[3] Three of the dead individuals had been tagged, but not yet assigned an experimental status; the other two had received gouge grafts. Therefore, we calculate the mortality in this group of experimental animals as 4% for gouge grafts and 0% for disk grafts, reversed-plug grafts,

---

2. Contrary to what might have been expected, mortality was higher in the group of siblings from the emerging nest than in the miscellaneous group of non-emerged hatchlings rescued from older nests. Seven of the nine deaths mentioned above were in the group of siblings (4 controls and 3 grafted animals). Two of the 10 deaths which occurred after arrival in Honolulu, but before work began, were also from these siblings, and 4 deaths had occurred before departure from French Frigate Shoals. The field party reported that the nest contained only about 40 eggs, of which approximately half hatched--further indications of a generally weak clutch.

3. All five deaths occurred in the holding tank population which included the 12 animals rescued after a tank overflow entailing a severe drop to the floor and an undetermined number of hours out of water. It is possible, but unprovable, that all five deaths could have been from this stressed group of individuals.

and controls. No emaciation or morbidity was noted, there was no apparent fungal infection, and no conspicuous biting damage.

A comparison of the condition of the animals in each shipment group, made from notes taken during the two post-operative inspections, is presented in Table 1.

In summary, there does seem to be a real difference in survivability between the animals in the two different shipments, with the hatchlings from the large, normal nests being the more vigorous, but there is no clear evidence from either shipment group of increased mortality risk due to the grafting treatment.

Graft success. Of 25 animals in the first shipment which had been given reversed-plug grafts and were still surviving on 15 October (almost a month after surgery), 8 (32%) showed complete or nearly complete loss of their grafts. Six of the eight failures were double plug operations--almost half of the 13 surviving animals which had been given double plugs. The other two failures were from the group of 12 surviving animals given single plug operations.

Of 29 animals from the second shipment given reversed-plug grafts (15 single and 14 double plugs), all were surviving on 15 October (15th day post-operative). None had lost their grafts and only four were noted as showing any signs of possible future graft loss.[4]

---

4. In almost all of these animals the pale, upper surface of the plug graft(s) had darkened so markedly that there was no longer any marked color contrast between graft and adjacent host tissues (more contrast remained on the underside of the shell). Whether the darkening of the pale, plug keratin is due to tissue degeneration or to normal pigment cells, and, if normal, whether it will persist or return to a lighter shade at a later time, cannot be determined at this time. Sacrifice of one or two animals for histological studies would shed some light on this matter.

Table 1. Comparison of Two Groups of *C. mydas* Hatchlings Following Grafting.

	SHIPMENT I 12/13 DAYS POST-OPERATIVE (on Sept.30,1980)	SHIPMENT II 15/22/23 DAYS POST-OPERATIVE (on Oct.15, 1980)	SHIPMENT I 27/28 DAYS POST-OPERATIVE (on Oct.15, 1980)
Total mortality (non-accidental) since arrival	14 of 53 (26%)	5 of 182 (2.7%)	19 of 53 (36%)
Mortality since beginning of experiment	4 of 43 (9%)	2 of 179 (1.1%)	9 of 43 (21%)
Deaths, Controls	3 of 13 (23%)	0 of 50 (0%)	4 of 13 (31%)
Deaths, Rev.-Plugs	1 of 30 (3.3%)	0 of 50 (0%)	5 of 30 (17%)
Deaths, Disk Grafts	-----	0 of 50 (0%)	-----
Deaths, Gouge Grafts	-----	2 of 50 (4%)	-----
Number noted with debility, fungus, biting damage, etc.	6 of 39 (15%)	0 of 179 (0%)	21 of 34 (62%)

At this stage it is impossible to say whether the differences noted between the two different reversed-plug groups is a function of time following the operation, or of the condition of the animals. It does seem reasonable to predict that double plugs in close proximity are a poorer risk than are single plugs.

The results obtained with reversed-plug grafts here are superior to those obtained with a group of loggerhead (Caretta caretta) hatchlings in Florida earlier this year. In the latter case, the punching was done with an unmodified leather punch, without rotation of the cutting edge and causing considerable compression in the plug tissue. This made the plug tapered, and it had a poor fit when replaced in the hole from which it was cut. The machined, thin-walled cutting tool, employed separately from the plier mechanism and capable of rotation while cutting, clearly does a better job and produces a better fit of the plug scion in its hole. It should be noted, however, that the tool employed in this case, machined to minimum wall thickness with the above features in mind, showed two problems: there was a tendency for the extremely thin cutting edge to double over after repeated use on the tough carapace tissues, and the necessary sharpening at intervals tended to produce a wavy cutting edge which required full 360° rotation in order to cut the plug free.

All 50 disk-grafted animals showed retention of both dorsal and ventral scions, and the 48 surviving gouge-grafted animals showed equally good retention of scions, as well as uncomplicated healing of the 18 plastral wounds which were left with only a

cement seal. No particularly noteworthy details were observed in the cases of the black carapacial scions on the pale plastral surfaces, but the pale scions on the animals' backs commonly showed differentiation into lighter and darker areas. It is our impression that the darker areas represent rapid tissue growth, visible through the lightly pigmented tissue of the graft scion. Whether this represents "take" of the graft and not wound-healing activity from surrounding tissues cannot be determined at this stage without sacrifice of a few animals for histological studies.

Disk or gouge plastral scions cut to include a seam between scutes and placed in a comparable cross-seam wound in the carapace, so that scion and host seams were aligned, seemed to show signs of splitting in the grafted plastral scion to match a degree of differential growth between the host-site carapace scutes. If this interpretation is accurate, and if there is the inferred predominance of keratin production from the anterior and medial edges of a carapace scute, one might expect the portion of the pale scion growing on the posterior edge of right costal scute 1 to erode away with time and disappear, while the other portion incorporated into the leading edge of right costal scute 2 might continue to produce pale tissue. Such a differential in growth rates, comparable to nail growth in humans, might then produce a pale streak, instead of a pale spot, on the carapace (assuming that the paleness of the grafted scion continues to be expressed throughout life).

Operation timing. Another feature of this process, which will be important if this technique is to be used in the field, is the

time necessary to complete each grafting operation. To be meaningful, thousands of newly emerged hatchlings would have to be treated, preferably on the nesting beach and under conditions of darkness, blowing sand, etc., always striving toward the ideal of handling a hatchling quickly, then setting it down to continue its normal procedure of sea-finding without further molestation. With this in mind, we kept time records of several short series of grafts. Admittedly, the laboratory conditions under which we worked are far easier than may be expected under normal beach conditions, but the exercise at least served to check on the possibility that the operations were too time-consuming, even under ideal conditions, to permit consideration of a massive field program.

A number of reversed-plug operations, timed individually, took from 1.5 to 5 minutes each. It is our impression that, with experience, 20 to 30 single-plug grafts per hour may be accomplished with ideal cutting tools.

Disk and gouge grafts (all reciprocal, involving two sites) were timed individually and in group series. In each test series, one Contractor did all animal-handling for the grafts, picking up the subject, making the cuts, transferring the scions, blotting, cementing, treating with ointment, and returning the subject to a container; the other Contractor affixed tags (not part of the projected field process) and served as recorder. Seven, 10, and 25 disk grafting operations took 13, 16, and 51 minutes (averages of 1.9, 1.6, and 2.0 minutes per hatchling). Thirteen gouge grafts took 28 minutes (average 2.2 minutes per hatchling). Every

effort was made to work at "usual" speed; in the case of the 25-animal series, the decision to record time was made at the end of the series when it was realized that the beginning time was known and the group could be used for this purpose.

We have every reason to believe that, with experience, more than 30 animals could be handled per operator per hour, allowing a 10-minute relaxation break each hour.

Concluding Remarks

We offer the following tentative, preliminary "conclusions":

1. There is no evidence that the grafting operation increases mortality rates or in any other way significantly disadvantages green turtle hatchlings.
2. The reversed-plug type of graft seems clearly less useful than disk or gouge grafts. Double reversed-plugs in close proximity to each other are less desirable than are single plugs.
3. There is no significant difference between Permabond (available in the U.S. and cheaper) and Histoacryl blau (available only by special import, more expensive) in drying time or efficacy as a wound-sealer.
4. The unfilled plastral wound left in a single-graft operation, sealed with the same surgical cement used to hold the scion in place on the carapace, presents no complications. It is not necessary to fill the plastral wound with a scion from the carapace, and this will save operation time. On the other hand, the complete, reciprocal operation takes little

longer and one can readily visualize the value of being able to confirm that a pale-spotted animal was a grafted individual by finding a dark spot on the plastron.

5. Without objective evidence from controls, the Contractors believe that smearing germicidal ointment over all treated areas is a desirable insurance measure in captive situations where the bacterial load to which the animals are exposed may be high.

6. It is strongly recommended that the monitoring through the coming year include weekly "in-hand" examination of each experimental animal, with replacement of all lost tags so that a complete history of each individual may be compiled.

7. Two animals from each treatment group of the population from the second shipment (19 September 1980) should be sacrificed to provide material for detailed histological examination of the grafts at their present stage. The Contractors are prepared to do this work, using a special fixative to prepare the tissues for electron microscopy. We would send the material to a colleague in Scotland who is an expert in both light and electron microscopy. There would be no cost to NMFS for this.

8. The operations can be performed with sufficient speed to accommodate the needs of a field marking program.

Acknowledgements

We wish to thank Dr. Wm. Gilmartin of NMFS, Honolulu for the courteous, considerate treatment extended to us, for seeing that the animals for this work were made available, and for providing transportation to and from Sea Life Park. For assistance with the work, and for chauffeur service, we thank Anjanette Perry who will continue to monitor the animals during the next 12 months.

We extend our aloha to the members of the Sea Life Park Reef Tank staff for their help and unfailing patience and good cheer through all the interference and obstruction that our work in their facility surely produced for them.

We wish to mention, especially, the Bishop Museum, where office space and equipment were made available to us for those aspects of our work which required them. We thank Dr. Creutz and his staff for their courtesy.

We thank Carla H. Kishinami for expert editorial assistance.

Literature Cited

Benedict, A. A., and L. W. Pollard. 1972. Three classes of immunoglobulins found in the sea turtle, Chelonia mydas. Folia Microbiol. 17:75-78. "Brief Reports."

Bustard, H. R. 1979. Population dynamics of sea turtles. Pages 523-540 in M. Harless and H. Morlock (eds.), Turtles: Perspectives and research. John Wiley & Sons, NY. 695 pp.

Carr, A. 1967. So excellent a fishe. Natural History Press, Garden City, NY. 248 pp.

Delaney, M. J. 1978. Introduction: Marking animals for research. Pages 2-10 in Stonehouse, B. (ed.), Animal marking: Recognition marking of animals in research. Macmillan Press, Ltd., London. 257 pp.

Forbes, A. M. 1972. Distribution of injected europium in hatchling Chelonia mydas L. and its considerations as a tag. Master's thesis, University of Rhode Island.

Green, D. 1979. Double tagging of green turtles in the Galapagos Islands. Marine Turtle Newsletter IUCN/SSC No. 13:4-9.

Hughes, G. R. 1975. The marine turtles of Tongaland. 8. Lammergeyer 22:8-18.

Plummer, M. V. 1979. Chapter 2. Collecting and marking. Pages 45-60 in M. Harless and H. Morlock (eds.), Turtles: Perspectives and research. John Wiley & Sons, NY. 695 pp.

No.	(1) Type or Treatment	(2) No. of Grafts	(3) Dorsal Scute(s) Treated	(4) Adhesive	(5) Date of Operation	(6) COMMENTS
4	R. Plug	D	last LM	H	9/17/80	Dead 10/1/80
5	R. Plug	S	last LM	P	9/18/80	Dead 10/11/80
6	Control	-	-----	-	9/17/80	Dead 9/18/80
7	R. Plug	S	last LM	P	9/18/80	
8	Control	-	-----	-	9/17/80	
9	Control	-	-----	-	9/17/80	Dead 9/18/80
10	R. Plug	S	last LM	P	9/18/80	Dead 9/20/80
11	Control	-	-----	-	9/17/80	Dead 9/19/80
12	Control	-	-----	-	9/17/80	Dead 10/13/80
13	Control	-	-----	-	9/17/80	
14	Control	-	-----	-	9/17/80	
15	R. Plug	S	last LM	H	9/17/80	
16	Control	-	-----	-	9/17/80	(note 7)
17	Control	-	-----	-	9/17/80	(note 7)
18	R. Plug	S	Last LM	H	9/17/80	
19	R. Plug	S	last LM	P	9/18/80	
20	R. Plug	D	last LM	P	9/18/80	
21	Control	-	-----	-	9/17/80	
22	R. Plug	S	last LM	H	9/17/80	
23	R. Plug	S	last LM	H	9/17/80	
24	R. Plug	S	last LM	H	9/17/80	
26	R. Plug	S	last LM	H	9/17/80	
27	R. Plug	S	last LM	H	9/17/80	
28	R. Plug	D	last LM	P	9/18/80	
29	R. Plug	D	last LM	P	9/18/80	
30	Control	-	-----	-	9/17/80	(note 7)
31	R. Plug	D	last LM	H	9/17/80	
32	R. Plug	S	last LM	H	9/17/80	Dead 10/2/80
33	R. Plug	S	last LM	P	9/18/80	
34	R. Plug	D	last LM	P	9/18/80	
35	R. Plug	S	last LM	P	9/18/80	
36	Control	-	-----	-	9/17/70	
37	Control	-	-----	-	9/17/80	
38	R. Plug	D	last LM	P	9/18/80	
39	R. Plug	D	last LM	H	9/17/80	
40	R. Plug	D	last LM	P	9/18/80	
41	R. Plug	D	last LM	H	9/17/80	
42	R. Plug	D	last LM	H	9/17/80	
43	R. Plug	D	last LM	H	9/17/80	(note 8)
44	R. Plug	S	last LM	P	9/18/80	(note 9)
45	R. Plug	D	last LM	H	9/17/80	Dead 10/8/80
46	R. Plug	D	last LM	P	9/18/80	(note 10)
47	R. Plug	D	last LM	P	9/18/80	(note 11)
48	Disk	R	RC2	H	9/23/80	
49	Disk	R	N2/RC1/RC2	H	9/23/80	
50	Disk	R	RC1	H	9/23/80	
51	Disk	R	RC1	H	9/23/80	
52	Disk	R	RC1	H	9/23/80	
53	Disk	R	RC1	H	9/23/80	
54	Disk	R	RC1/RC2	H	9/23/80	
55	Disk	R	RC1	H	9/23/80	
56	Disk	R	RC1	H	9/23/80	
57	Disk	R	RC1	H	9/23/80	
58	Disk	R	RC1	H	9/23/80	

Tag No. (1)	Type of Treatment (2)	No. of Grafts (3)	Dorsal Scute(s) Treated (4)	Adhesive (5)	Date of Operation (6)	COMMENTS
59	Disk	R	RC1	H	9/23/80	
60	Disk	R	N2/RC1/RC2	H	9/23/80	
61	Disk	R	RC1	H	9/23/80	
62	Disk	R	N2/RC1/RC2	H	9/23/80	
63	Disk	R	RC1	H	9/23/80	
64	Disk	R	N2/RC1	H	9/23/80	
65	Disk	R	RC1	H	9/23/80	
66	Disk	R	RC1	H	9/23/80	
67	Disk	R	RC1	H	9/23/80	
68	Disk	R	RC1	H	9/23/80	
69	Disk	R	RC1	H	9/23/80	
70	Disk	R	RC1	H	9/23/80	
71	Disk	R	RC1	H	9/23/80	
72	Gouge	R	RC1	P	9/24/80	
73	Gouge	R	RC1	P	9/24/80	
74	Disk	R	RC2	H	9/23/80	
75	Gouge	R	RC1	P	9/24/80	
76	Gouge	S	RC1	P	9/24/80	
77	Gouge	S	RC1	P	9/24/80	
78	Gouge	R	RC1	P	9/24/80	
79	Gouge	R	RC1	P	9/24/80	
80	Gouge	R	RC1	P	9/24/80	
81	Gouge	R	RC1	P	9/24/80	
82	Gouge	R	RC1	P	9/24/80	
83	Gouge	R	RC1	P	9/24/80	
84	Gouge	R	RC1	P	9/24/80	
85	Gouge	S	RC1	P	9/24/80	
86	Gouge	R	RC1	P	9/24/80	
87	Gouge	S	RC1	P	9/24/80	
88	Gouge	R	RC1	P	9/24/80	
89	Gouge	S	RC1	P	9/24/80	
90	Gouge	R	RC1	P	9/24/80	
91	Gouge	R	RC1	P	9/24/80	
92	Gouge	S	RC1	P	9/24/80	
93	Gouge	S	RC1	P	9/24/80	
94	Gouge	R	RC1	P	9/24/80	
95	Gouge	S	RC1	P	9/24/80	
96	Gouge	S	RC1	P	9/24/80	
97	Control	-	-----	-	9/26/80	
98	Control	-	-----	-	9/26/80	
99	Control	-	-----	-	9/26/80	
100	R. Plug	S	last LM	P	9/30/80	
101	Control	-	-----	-	9/26/80	
102	R. Plug	D	last LM	P	9/30/80	
103	R. Plug	D	last LM	P	9/30/80	
104	R. Plug	S	last LM	P	9/30/80	
105	Control	-	-----	-	9/26/80	
106	Control	-	-----	-	9/26/80	
107	R. Plug	D	last LM	P	9/30/80	
108	Control	-	-----	-	9/26/80	
109	R. Plug	S	last LM	P	9/30/80	
110	R. Plug	S	last LM	P	9/30/80	

No.	(1) Type of Treatment	(2) No. of Grafts	(3) Dorsal Scute(s) Treated	(4) Adhesive	(5) Date of Operation	(6) COMMENTS
12	R. Plug	D	last LM	P	9/30/80	
13	R. Plug	D	last LM	P	9/30/80	
14	Control	-	-----	-	9/26/80	
15	R. Plug	S	last LM	P	9/30/80	
16	R. Plug	D	last LM	P	9/30/80	
17	R. Plug	S	last LM	P	9/30/80	
18	Control	-	-----	-	9/26/80	
19	R. Plug	D	last LM	P	9/30/80	
20	Control	-	-----	-	9/26/80	
21	Control	-	-----	-	9/26/80	
22	R. Plug	S	last LM	P	9/30/80	
23	R. Plug	D	last LM	P	9/30/80	
24	R. Plug	S	penult. LM	P	9/30/80	
25	R. Plug	D	last LM	P	9/30/80	
26	R. Plug	D	last LM	P	9/30/80	
27	Control	-	-----	-	9/26/80	
28	R. Plug	S	last LM	P	9/30/80	
29	Control	-	-----	-	9/26/80	
30	R. Plug	S	last LM	P	9/30/80	
31	R. Plug	S	last LM	P	9/30/80	
32	R. Plug	D	last LM	P	9/30/80	
33	R. Plug	S	last LM	P	9/30/80	
34	Control	-	-----	-	9/26/80	
35	Control	-	-----	-	9/26/80	
36	Control	-	-----	-	9/26/80	
37	Control	-	-----	-	9/26/80	
38	R. Plug	D	last LM	P	9/30/80	
39	R. Plug	S	last LM	P	9/30/80	
40	R. Plug	D	last LM	P	9/30/80	
41	Control	-	-----	-	9/26/80	
42	R. Plug	D	last LM	P	9/30/80	
43	Control	-	-----	-	9/26/80	
44	R. Plug	S	last LM	P	9/30/80	
45	R. Plug	S	last LM	P	9/30/80	
1	Disk	R	RC1/RC2	H	9/23/80	
2	Disk	R	RC1/RC2	H	9/23/80	
3	Disk	R	RC1/RC2	H	9/23/80	
4	Disk	R	RC1/RC2	H	9/23/80	
5	Disk	R	RC1/RC2	H	9/23/80	
6	Disk	R	RC1/RC2	H	9/23/80	
7	Disk	R	RC1/RC2	H	9/23/80	
8	Disk	R	RC1/RC2	H	9/23/80	
9	Disk	R	RC1/RC2	H	9/23/80	
10	Disk	R	RC1/RC2	H	9/23/80	
11	Disk	R	RC1/RC2	H	9/23/80	
12	Disk	R	RC1/RC2	H	9/23/80	
13	Disk	R	RC1/RC2	H	9/23/80	
14	Disk	R	RC1/RC2	H	9/23/80	
15	Disk	R	RC1/RC2	H	9/23/80	
16	Disk	R	RC1/RC2	H	9/23/80	
17	Disk	R	RC1/RC2	H	9/23/80	
18	Disk	R	RC1/RC2	H	9/23/80	

Tag No. (1)	Type of Treatment (2)	No. of Grafts (3)	Dorsal Scute(s) Treated (4)	Adhesive (5)	Date of Operation (6)	COMMENTS
19	Disk	R	RC1/RC2	H	9/23/80	
20	Disk	R	RC1/RC2	H	9/23/80	
21	Disk	R	RC1/RC2	H	9/23/80	
22	Disk	R	RC1/RC2	H	9/23/80	
23	Disk	R	RC1/RC2	H	9/23/80	
24	Disk	R	RC1/RC2	H	9/23/80	
25	Disk	R	RC1/RC2	H	9/23/80	
26	Gouge	R	RC1/RC2	H	9/24/80	Dead 9/28/80
27	Gouge	R	RC1/RC2	H	9/24/80	
28	Gouge	R	RC1/RC2	H	9/24/80	
29	Gouge	R	RC1/RC2	H	9/24/80	
30	Gouge	R	RC1/RC2	H	9/24/80	
31	Gouge	R	RC1/RC2	H	9/24/80	
32	Gouge	R	RC1/RC2	H	9/24/80	
33	Gouge	R	RC1/RC2	H	9/24/80	
34	Gouge	R	RC1/RC2	H	9/24/80	
35	Gouge	R	RC1/RC2	H	9/24/80	
36	Gouge	R	RC1/RC2	H	9/24/80	
37	Gouge	R	RC1/RC2	H	9/24/80	
38	Gouge	R	RC1/RC2	H	9/24/80	
39	Gouge	R	RC1/RC2	H	9/24/80	
40	Gouge	R	RC1/RC2	H	9/24/80	
41	Gouge	R	RC1/RC2	H	9/24/80	Dead 9/29/80
42	Gouge	S	RC1/RC2	H	9/24/80	
43	Gouge	S	RC1/RC2	H	9/24/80	
44	Gouge	S	RC1/RC2	P	9/24/80	
45	Gouge	S	RC1/RC2	P	9/24/80	
46	Gouge	S	RC1/RC2	P	9/24/80	
47	Gouge	S	RC1/RC2	P	9/24/80	
48	Gouge	S	RC1/RC2	P	9/24/80	
49	Gouge	S	RC1/RC2	P	9/24/80	
50	Gouge	S	RC1/RC2	P	9/24/80	
51	Control	-	-----	-	9/26/80	
52	Control	-	-----	-	9/26/80	
53	Control	-	-----	-	9/26/80	
54	Control	-	-----	-	9/26/80	
55	Control	-	-----	-	9/26/80	
56	Control	-	-----	-	9/26/80	
57	Control	-	-----	-	9/26/80	
58	Control	-	-----	-	9/26/80	
59	Control	-	-----	-	9/26/80	
60	Control	-	-----	-	9/26/80	
61	Control	-	-----	-	9/26/80	
62	Control	-	-----	-	9/26/80	
63	Control	-	-----	-	9/26/80	
64	Control	-	-----	-	9/26/80	
65	Control	-	-----	-	9/26/80	
66	Control	-	-----	-	9/26/80	
67	Control	-	-----	-	9/26/80	
68	Control	-	-----	-	9/26/80	
69	Control	-	-----	-	9/26/80	
70	Control	-	-----	-	9/26/80	

Tag No.(1)	Type of Treatment(2)	No. of Grafts(3)	Dorsal Scute(s) Treated(4)	Adhesive(5)	Date of Operation(6)	COMMENTS
1	Control	-	-----	-	9/26/80	
2	Control	-	-----	-	9/26/80	
3	Control	-	-----	-	9/26/80	
4	-----	-	-----	-	9/26/80	Dead 9/29/80(see note 1)
5	Control	-	-----	-	9/26/80	
6	Control	-	-----	-	9/26/80	
7	Control	-	-----	-	9/26/80	
8	-----	-	-----	-	9/26/80	Dead 9/30/80(see note 1)
9	Control	-	-----	-	9/26/80	
10	Control	-	-----	-	9/26/80	
11	Control	-	-----	-	9/26/80	
12	Control	-	-----	-	9/26/80	
13	Control	-	-----	-	9/26/80	
14	-----	-	-----	-	9/26/80	Dead 9/30/80(see note 1)

NOTES:

1. Tags #1, #2, #3, and #25 not used. First shipment of hatchlings received tags numbered 47 and below. Tags #48 through #145 used on larger clutch, second shipment (from female #200; all these hatchlings are siblings). Tags #146 through #200 not used. Tags #201 and above used on remainder of second shipment (mostly siblings, with accidental admixture of 12 individuals from female #200's clutch). Hatchlings #274, #278, and #300 died before being assigned to either control or treatment status. Contractors tagged #48-#97, #201-#250; NMFS staff tagged others.
2. "R. Plug" = Reversed-Plug Graft.
3. "D"= "Double" (2 reversed-plugs side by side in same marginal scute).
   "S"= "Single" (either single reversed-plug or single graft of plastral scion to carapace wound).
   "R"= "Reciprocal" (2 grafts per animal, with plastral scion to carapace and carapacial scion to plastron).
4. "LM"= "Left Marginal"; "N2"= 2nd Neural (from anterior); "RC1"= 1st Right Costal; "RC2"= 2nd Right Costal. Multiple entries indicate that the graft crossed suture line(s) between scutes (e.g. N2/RC1/RC2).
5. "H"= Histoacryl blau; "P"= Permabond
6. In the case of Controls, date entered indicates date tag was affixed.
7. When work began on 17 Sept., #16 and #17 isolated from others, not eating well and appeared weak; #30 isolated, with apparent fungus infection on shell and skin.
8. Last left marginal scute abnormally small; the two plugs were touching.
9. Congenital indentation at tagging site; tag precariously affixed at junction between last right marginal and right pygal scutes.
10. The two plugs were touching (operator's error)
11. Last right marginal abnormally small; tag on penultimate right marginal.

Southwest Fisheries Center Administrative Report H-80-18

REPORT ON FISH AGGREGATING DEVICES WORKSHOP

By

Walter M. Matsumoto, Rapporteur
Honolulu Laboratory, Southwest Fisheries Center
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

December 1980

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

REPORT ON FISH AGGREGATING DEVICES WORKSHOP

I. INTRODUCTION

An informal workshop on fish aggregating devices (FAD) was held on October 23, 1980 at the National Marine Fisheries Service (NMFS), Honolulu Laboratory. The purpose of the workshop was to discuss the mounting problem of FAD losses.

The agenda agreed upon was to describe in detail the construction of mooring lines of the various FAD presently in use, to identify the causes of mooring line failures, and to determine the changes necessary in reducing FAD losses. The discussions were followed by presentation of catch results to date around the Hawaii statewide FAD system and of the ecological build-up of fish populations around the FAD.

II. GEAR CONSTRUCTION AND LOSSES

A. NMFS Experimental FAD

The NMFS used two types of mooring configurations. The first type (Figure 1a) consisted of a 50-ft length of chain attached to the buoy with a 5/8-in. galvanized shackle. The lower end of the chain was shackled to a 5/8-in. galvanized swivel and, in turn, to the 5/8-in. polypropylene rope. The lower end of the rope was attached to the anchor chain in a similar manner with a swivel and shackles. An intermediate weight of large chain links was connected to the rope section by a loop of either 5/16- or 3/8-in. chain with comparable sized shackles. The lower end of the intermediate weight was also fitted with a galvanized swivel. All rope ends were spliced to about 14 in. around heavy-duty cable thimbles. Sections of rope coils were joined together by long splices in which about 1 fathom of line was twisted around each other and each end spliced into the opposite line for a length of about 15 in. All splices, including that around thimbles, were seized with nylon twine at two places. All shackle pins were secured with galvanized wire.

The second type (Figure 1b) was constructed in a similar fashion, except that the 50-ft chain length at the buoy end was replaced with a 100-ft length of 3/8-in. galvanized wire rope. Both ends of the wire rope were fitted with 3/8-in. heavy duty thimbles and fastened with three safety wire grips.

The original set of four devices off Oahu and Lanai included a short section of 3/8-in. wire rope, fitted with floats, which was attached to the mooring line between the rope and anchor chain. Because copper nico-press sleeves were used to fasten the thimbles at both ends of the wire rope, this part of the line failed after about 2 months due to electrolysis. This section was omitted from later buoys because the buoyance of the polypropylene rope was sufficient to keep the line off the bottom.

During the remainder of the experiment, six more devices were lost at the four sites. Three from undetermined causes after 4, 17, and 20 months, two from causes other than mooring line design failure (one by rope chafing on bottom ledge, the other after having been dragged by currents to shallower waters where line chafing presumably occurred at the intermediate weight), and one due to loss of shackle pin. Only two of the six lost buoys were recovered.

Off Kona, four devices were lost at two sites. The initial two devices made of wooden rafts were lost as the rafts broke apart during a storm with winds in excess of 80 knots. The two replacement buoys, made of 55-gal drums, were moored by lines consisting of 100 ft of 3/8-in. wire rope at the top in place of the chain section, were also lost; one from undetermined causes, the other, as the cable grips became loose.

B. American Samoa FAD

The FAD used in American Samoa consisted of buoys made of three 55-gal drums filled with foam. The NMFS designed mooring configuration differed slightly from that used in Hawaii. Two types of lines were designed for shallow and deep moorings. The single shallow mooring (Figure 2a) consisted of a 10-ft length of 1/2-in. chain shackled to a padeye on the buoy. A galvanized swivel was shackled to the chain section and to a length of 3/8-in. wire rope. A 150-ft length of chain was shackled to the anchor and the wire rope. Each end of the wire rope was secured around a thimble with three safety wire grips and coated with fiberglass. All shackle pins were secured with galvanized wire.

The nine deep moorings design (Figure 2b) consisted of 10 ft of chain, followed by 100 ft of wire rope and 5/8-in. polypropylene rope. The rope end was attached to a 30-ft long anchor chain. An intermediate weight of large chain links was shackled into the rope section. Galvanized swivels were placed at the lower end of the intermediate chain weight and at the lower end of the rope. All connections were made with 5/8-in. galvanized shackles and the shackle pins were secured with galvanized wire and fiberglassed.

After learning about slippage in the safety wire grips in the Hawaiian experiment, the wire rope section was altered so that it was removed from some of the deep moorings and added on to others (doubled up). Thus, five buoys were set without the wire rope section, two were set with double wire rope section, and two were set with single wire rope section. The wire rope on the shallow mooring was also doubled up.

Of the 10 devices moored in October 1979, 6 were either lost or reported missing to date. Of the four remaining buoys, three had no wire rope section and one (shallow mooring) had double wire ropes. Of the buoys that broke free, one did so as a result of being overrun by a tugboat. The other confirmed breakage occurred at the rope section beneath the wire rope at the end of the splice. It was believed that the absence of a swivel at the junction of the wire rope and the rope section was the cause of line failure. The broken end of the rope showed signs of having been twisted.

C. Eastern Pacific FAD

The Inter-American Tropical Tuna Commission moored three FAD from August 26 to September 22, 1980 in the eastern Pacific between lat. 10°N and 15°N, 390 to 630 mi offshore in depths of 1,600 to 2,200 fathoms. A description of the devices and mooring line construction was presented as an alternative to the systems presently in use.

The device was a 4 ft x 12 ft x 8 in. raft made of plyboard and filled with foam. The mooring consisted of a swivel, attached to a cross-piece on the raft, followed by 20 fathoms of 1/2-in. wire rope and the rope section. The ends of the wire rope were spliced around thimbles. The rope section consisted mostly of 5/8-in. polypropylene rope in the upper section, with the lower sections of 3/4-in. and 7/8-in. rope. One-inch galvanized swivels were inserted between rope coils and the ends of the rope were knotted to the swivel eyes. At the lower end, the rope end was knotted around four tire sidewalls. Three 1-in. polypropylene rope bridles led from the four tire sidewalls to two tire sidewalls imbedded in concrete in each of three 55-gal. drums. The mooring line had a scope of nearly 1:1.

Although the FAD have not been in place long enough to prove their durability, one of them has withstood a hurricane with winds of up to 105 knots. Because the raft is constructed of lumber, it is expected that the raft will break up in due time. The lack of any ballast on the raft will make it prone to capsizing, and one raft has already done so.

D. Palau FAD

The Palau FAD (Figure 3) was patterned after that of the Hawaii State system (see below), but with some changes. The ballast and mast were

made of a single length of 4-in. pipe which projected 8 ft below and 6 ft above the buoy. The attachment for the mooring line was a single L-shaped steel plate bolted onto the underside of the buoy.

The mooring line consisted of a 20-ft long 1/2-in. chain which was looped through a hole in the attachment and shackled. The lower end of the chain was shackled to a 3/4-in. galvanized swivel and, in turn, to the main section of 5/8-in. polypropylene rope fitted with a galvanized thimble. The lower end of the rope section was shackled to a swivel and 50-ft of 1/2-in. chain which was shackled onto a 1,000-lb marine anchor. An intermediate weight of large chain links was shackled onto the line with a galvanized swivel attached at the lower end. The rope sections were connected to each other by long double splices and three or four swivels were spaced along the length of the rope section. All shackle pins were secured with galvanized wire.

Six FAD were moored in late July and early August, 1980 in depths of 600 to 2,022 fathoms, all with line scope of 1.6:1. To date, one FAD has broken loose. The cause of line failure has not been determined, but because the FAD were anchored in areas with numerous high steep ridges, there was a possibility that the line may have chafed against the ridges.

E. Guam FAD

The Guam FAD, initially, were made of three 55-gal drums filled with foam and with four leg supports to the ballast pipe (Figure 4). Chain bridles attached to the middle of the buoy were linked to 75 ft of chain with shackles and a swivel. The remainder of the mooring line was similar to that of the NMFS line, but the anchor was made of T-shaped concrete block.

Two devices were anchored in 300 and 510 fathoms in December 1979 and January 1980. Due to insufficient intermediate weight, the excess rope floated to the surface. The first device broke free within 1 week and was subsequently retrieved. It was believed that the floating line was severed by the propellor of a fishing boat. Additional weight was added to the mooring line of the second buoy as a corrective measure. This device also broke free in May. It was assumed that the break had occurred either at the intermediate weight or at a splice.

On the replacement FAD, the design was altered to a tire platform type and the rope size was increased to 3/4 in. Additional padeyes were placed on the buoy to permit small boats to tie up to it.

One of the two buoys deployed in April and June broke free recently. The break had occurred at the junction between the bridle and the upper chain section. The shackle was missing.

F. Marianas FAD

The Marianas FAD was made of three drum buoys with the mooring line attached to the end of the ballast pipe. The mooring line (Figure 5) consisted of 50-ft lengths of chain at the buoy and anchor, with a main section of 5/8-in. polypropylene rope, that contained an intermediate weight. Swivels were shackled onto the ends of the chain sections, including both ends of the intermediate weight, and another in the rope section below the intermediate weight. A concrete block weighing 3 tons was used as the anchor.

Of five FAD anchored during February-March 1980, all have been lost. The FAD had been deployed without the aid of radar or depth recorder; consequently, one device was set too deep and disappeared from sight, two others were set too shallow and were probably lost as a result of the line chafing on the bottom at the intermediate weights. Two others showed signs of having been run over by passing vessels prior to their disappearance.

G. Hawaii Fish and Game FAD

The Hawaii Fish and Game FAD (Figure 6) were constructed of 6-ft diameter, 22-in. wide rubber tire, enclosed by steel plates over the open sides and fitted with polyurethane foam. A mast of pipe and PVC (polyvinyl chloride) pipe extension was attached to the top plate. The mast extension contained a battery pack topped with a flashing light. Vertical steel gussets welded to the top plate served to support the mast. An 8-in. pipe, 8 ft long, filled with 350 lb of scrap iron was welded to the bottom plate and served as ballast.

The mooring line configuration is shown in Figure 7. The top of the bridle was shackled to two padeyes through a split chain connecting link. The lower end of the bridle was connected to a bronze swivel by split chain connecting links and the swivel was shackled to 100 ft of 1/2-in. chain. The lower end of the chain was attached to a swivel through a split chain link, and the swivel was shackled to the rope end fitted with a 3/4-in. Newco bronze thimble. Similar linkages were made below the intermediate chain weight and at the anchor chain. The top of the intermediate chain weight was linked without any swivel.

The FAD was moored to a 3,000-lb Baldt- or Danforth-type anchor to which 30 ft of 1/2-in. chain was attached with a 3/4-in. shackle and split chain link. The body of the mooring line consisted of 3/4-in. polypropylene medium-lay rope. The rope sections were connected to each other by a single splice consisting of about 10 tucks.

Twenty-six FAD were moored around the main Hawaiian Islands between May and July between May and July 1980 in depths ranging from 250 to 1,200 fathoms. To date seven FAD have broken loose, three of which were recovered. One of the breaks was due to a tugboat towline. The second was probably due to splice failure, either at a thimble or between rope sections. The latter showed signs of electrolysis at the

bronze swivel after 5 months; however, bronze thimbles showed little, if any, corrosion. The causes of failure of the other five FAD were undetermined.

III. IDENTIFYING PROBLEM AREAS

Of the 33 reported losses to date, 17 definite and 4 probable failures were identified. Twelve causes of failures were not determined, since the buoys were not recovered. The number of definite and probable failures are tabulated below:

Failure	Definite	Probable	Total	Cause
1. Shackle	2		2	Fabrication
2. Rope splice	1	1	2	Fabrication
3. Cable grip	1	2	3	Fabrication/design
4. Nico-press sleeve	4		4	Design
5. Rope twist	1		1	Design
6. Rope cut by propeller	1		1	Design
7. Rope chafing	4	1	5	Setting error/ design
8. Buoy set too deep	1		1	Setting error
9. Run over by tugboat	2		2	Accidental/design
	17	4	21	

Remarks on Itemized Failures

1. Shackle failure usually occurred as a result of the pin working itself loose. This can be delayed to some extent by securing the pin with galvanized wire, but there is always the possibility that the wire used could be too small and corrode within a short time, or that some of the shackles could be overlooked and not be secured at all. Mr. Ian Blogg, who has had wide experience with long-term deep moorings, noted also that he has observed shackles with the pin completely corroded.

2. Poor splicing, particularly single, short splices, and splices that are loose, could be pulled free. This is especially so when using slippery synthetic ropes made of such materials as polypropylene and nylon.

3. Cable grip failure was probably due to insufficient or uneven tightening of the two bolts. The buoys, in this case, were not out long enough for corrosion to set in, but the small bolts on the grip could corrode in due time.

4. The nico-press sleeve failure resulted from electrolysis caused by using copper sleeves on galvanized steel wire rope. The failure occurred during the initial experimental stage in the development of the buoys.

5. Rope twist caused by the absence of a swivel between the top chain section and the rope section resulted in a break in the rope adjacent to the splice. The twist was imparted either by buoy rotation or rotation of the rope, or both.

6. The severing of the mooring line by a boat's propeller resulted from failure to attach sufficient weight to the rope. This allowed the excess line to float to the surface, where it was overrun by a boat.

7. Rope chafing was largely due to misplacement of the buoys. The buoys were placed too close to bottom ledges or anchored in depths much shallower than intended. In the latter case, chafing is believed to have occurred when the intermediate weight reached the bottom. Rope chafing can also occur when the currents are strong enough to drag the buoy anchor. One buoy was dragged into waters shallower than the intermediate weight and was eventually lost.

8. This buoy was set in waters deeper than intended due to lack of proper instrumentation, i.e., depth recorder and navigational instruments.

9. The rope section of the mooring lines of two buoys were severed by tugboat towline. In one instance the tugboat approached too close to a buoy out of curiosity; in another incident the tugboat, most likely, failed to notice the buoy.

IV. CORRECTIVE MEASURES

Most of the failures can be considered as one time occurrences. Failures stemming from the use of cable grips and copper sleeves on steel wire rope need not reoccur if these items are not used in future fabrication. Incidences of rope being severed by propellers also need not occur if all are aware of the buoyancy of polypropylene rope and adjust it with an intermediate weight. Setting the buoys too shallow, resulting in rope chafing, and setting them too deep, resulting in complete submergence, need not occur if the buoys are set with the aid of proper navigational and depth-sounding equipment.

Other failures involving shackles, rope splices, and rope twists are more serious, since they can occur in future moorings. These require extreme care in fabrication. Shackle failures can be reduced if the pins are secured and coated with epoxy or fiberglass resin. The epoxy and resin will inhibit corrosion and also freeze the pin and prevent it from working itself loose. An alternative would be to replace all shackles with oversized split chain links. This too should be coated with epoxy or resin.

Because of the numerous rope splices required to construct a deep mooring line, it is imperative that the splices are securely made. This is especially critical with synthetic rope since this type of rope are prone to slip. For added security, the rope ends should be double-spliced, with each splice made at least 15 to 18 in. long and seized with twine at two or three places.

Line breaks due to twisting can be avoided by the addition of sufficient number of swivels at critical places. These are at the ends of the top

and bottom chain sections and at the lower end of the intermediate weight. Additional swivels may be added to the top of the intermediate weight and midway on the rope below the intermediate weight.

The swivels presently used, chain-link type, were suggested as being of inferior quality. Galvanized, barrel-type swivels with bearings were considered better since they were free to turn under heavy load.

One other problem that needed consideration was the avoidance of electrolysis which occurs when fittings made of different metals are placed next to each other. All fittings, thus, should be of uniform metals.

Mr. Blogg presented his ideas on ideal moorings. For moorings in excess of 500 m, he preferred a round buoy (Figure 8) with a line scope of 1:1, with bearing race swivels at the buoy, top and bottom of rope section. Because strain on the mooring line was concentrated in the upper 100 ft, the first section to approximately 20 fathoms should be of chain. For shallower moorings, he suggested an all chain tether consisting of a heavier chain section at the bottom attached to a dome-shaped anchor, the last to prevent the chain from winding around it. To overcome the weight problem, part of the mooring line could be of wire rope jacketed with a coating of epoxy. Epoxy fitted sockets and swivels were to be used at the ends of the wire rope. Such a mooring could withstand a current force of up to 4 knots.

V. CATCH RESULTS AROUND HAWAII FISH AND GAME FAD

Mr. Robert Nishimoto presented the catch results of the Hawaii statewide buoy system. To obtain catch data, the Hawaii Fish and Game distributed 5,000 postpaid cards. They obtained a response of about 3%.

The reported catch from April through mid-September 1980 was 237,300 lb. The breakdown of catches by major islands were: Kauai, 18,800 lb; Oahu, 168,300 lb; Maui-Molokai-Lanai, 31,704 lb; and Hawaii, 18,500 lb. Eighty-five to ninety-three percent of the catch at all the islands consisted of skipjack tuna. Other species taken around the buoys were yellowfin tuna, bigeye tuna, kawakawa, mahimahi, ono, striped marlin, blue marlin, and spearfish.

VI. BIOLOGICAL ASSESSMENT OF THE HAWAII FISH AND GAME FAD

Dr. Richard Brock presented preliminary results of his study on colonization and biomass build-up around the Hawaii buoys. Monitoring a newly redeployed buoy for a period of 36 days provided data on the colonization process. Juveniles of oceanic driftfishes, Psenes cyanophrys, began recruiting to the buoy within 15 minutes. The number of species increased rapidly to about ten in 15 to 20 days and remained steady through the 36th day. The data also showed that there was a turnover of fish species at the buoys and that a turnover rate (the number of fish species leaving or disappearing from the buoy area divided by the return or recruitment of new species) of 1.0 was attained in 20 days. This turnover was found to

occur in about half of the fish species present around the buoy. The driftfish; large filefish, Alutera scripta; kahala, Seriola dumerili; yellow papio, Gnathanodon speciosus; opelu, Decapterus macarellus; and mahimahi were all regular buoy residents.

Dr. Brock also reported that the standing crop of fishes, observed over this period at U buoy, was found to increase exponentially over time. One buoy deployed for more than 180 days had a standing crop of yellowfin tuna estimated at 1,600 metric tons. The yellowfin tuna school, consisting of large fish, 55 to 70 kg in weight, engaged in feeding activity at the surface in the morning and at dusk, and spent the remainder of the day as a nonfeeding school 80 to 200 m beneath the buoy.

Other observations at the buoys indicated that (a) schools of opelu were usually found above the yellowfin tuna school, (b) small forage fish near the buoys were generally wiped out by large tunas feeding on them, (c) there were many shoreside fish build-up around the buoys, but they lasted only for short periods before being preyed upon, and (d) the arrival of boats to the buoys caused the fish groups to sound.

VII. PARTICIPANTS

Ian Blogg	ALA-PAC, Seattle, Washington
Richard E. Brock	Hawaii Institute of Marine Biology, Honolulu, Hawaii
Patrick Bryan	Office of Marine Resources, American Samoa
Doyle E. Gates	Western Pacific Program Office, Southwest Region (SWR), Honolulu, Hawaii
Mike Gawel	East-West Center, Honolulu, Hawaii
Richard M. Howell	Guam Fishermen's Cooperative Assn., Agana, Guam
Gerson Jackson	Marine Resources Division, Kosrae, Micronesia
Alvin Katekaru	Hawaii Division of Fish and Game, Honolulu, Hawaii
Joseph Matanane	Government of Guam, Agana, Guam
David Nada	Pacific Tuna Development Foundation, Honolulu, Hawaii
John J. Naughton	Western Pacific Program Office, SWR, Honolulu, Hawaii
Robert T. Nishimoto	Hawaii Division of Fish and Game, Honolulu, Hawaii
Eugene Nitta	Western Pacific Program Office, SWR, Honolulu, Hawaii
Toshiro Paulis	Trust Territory Marine Resources Division, Saipan, Northern Marianas
Doug Souter	Living Marine Resources, San Diego, California
Joaquin P. Villagomez	Marine Resources Development Division, Saipan, Northern Marianas

Convenor

Richard S. Shomura	Honolulu Laboratory, Southwest Fisheries Center, NMFS, Honolulu, Hawaii

Rapporteur

Walter M. Matsumoto	Do.

Figure 1. NMFS mooring line configuration.

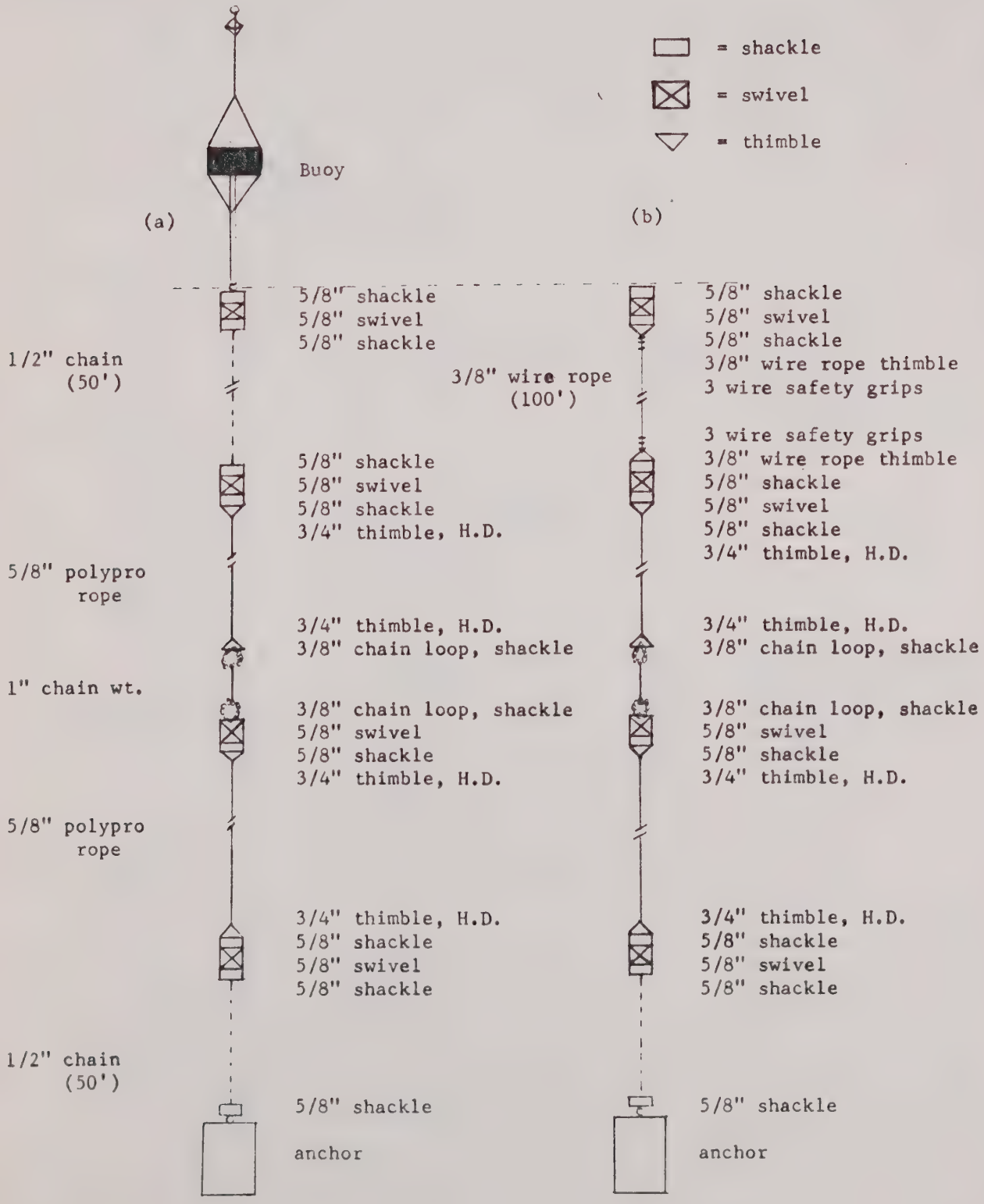


Figure 2. American Samoa mooring line configuration.

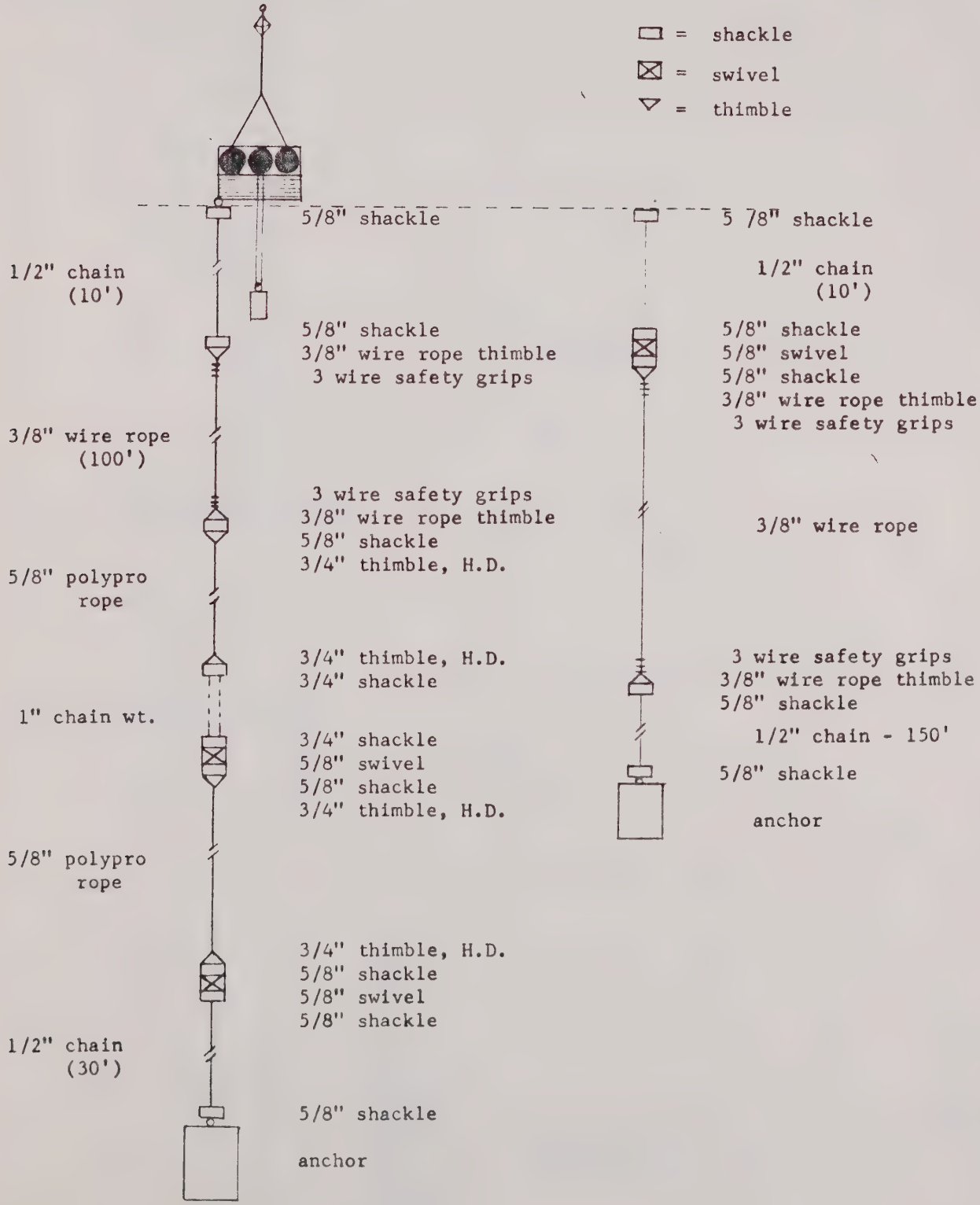


Figure 3. Palau FAD and mooring configuration.

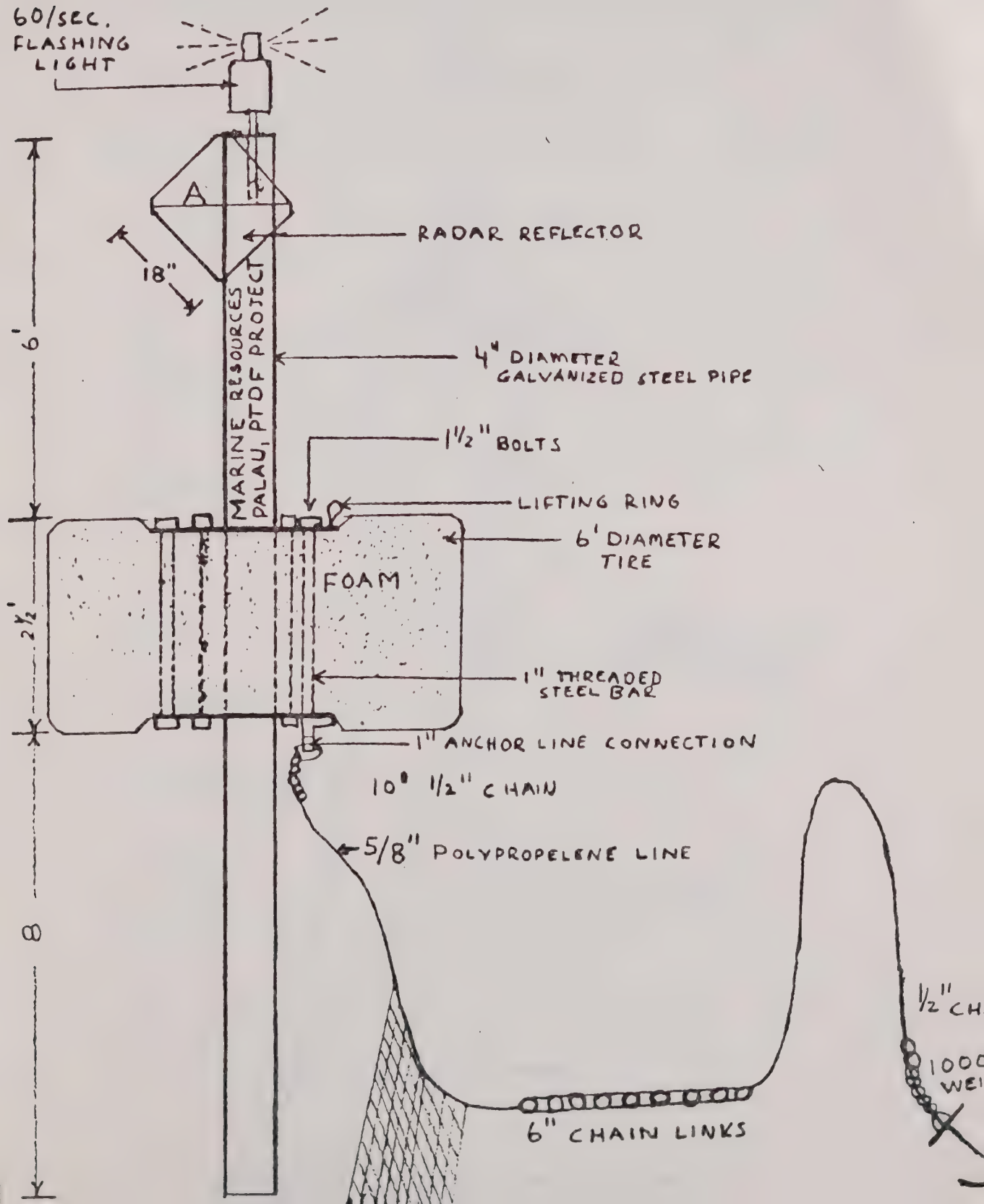


Figure 4. Guam FAD and mooring configuration.

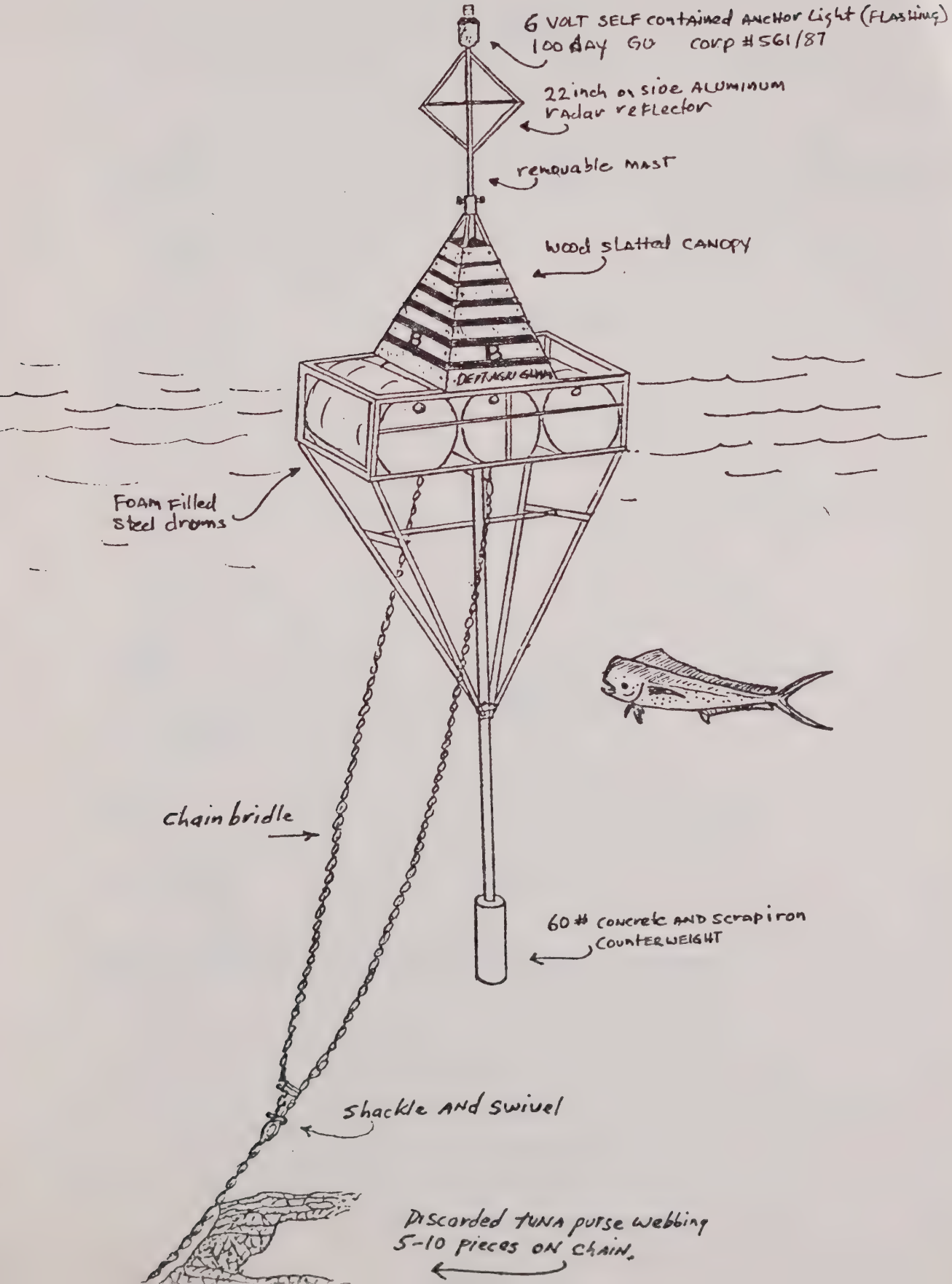


Figure 5. Marianas FAD mooring configuration.

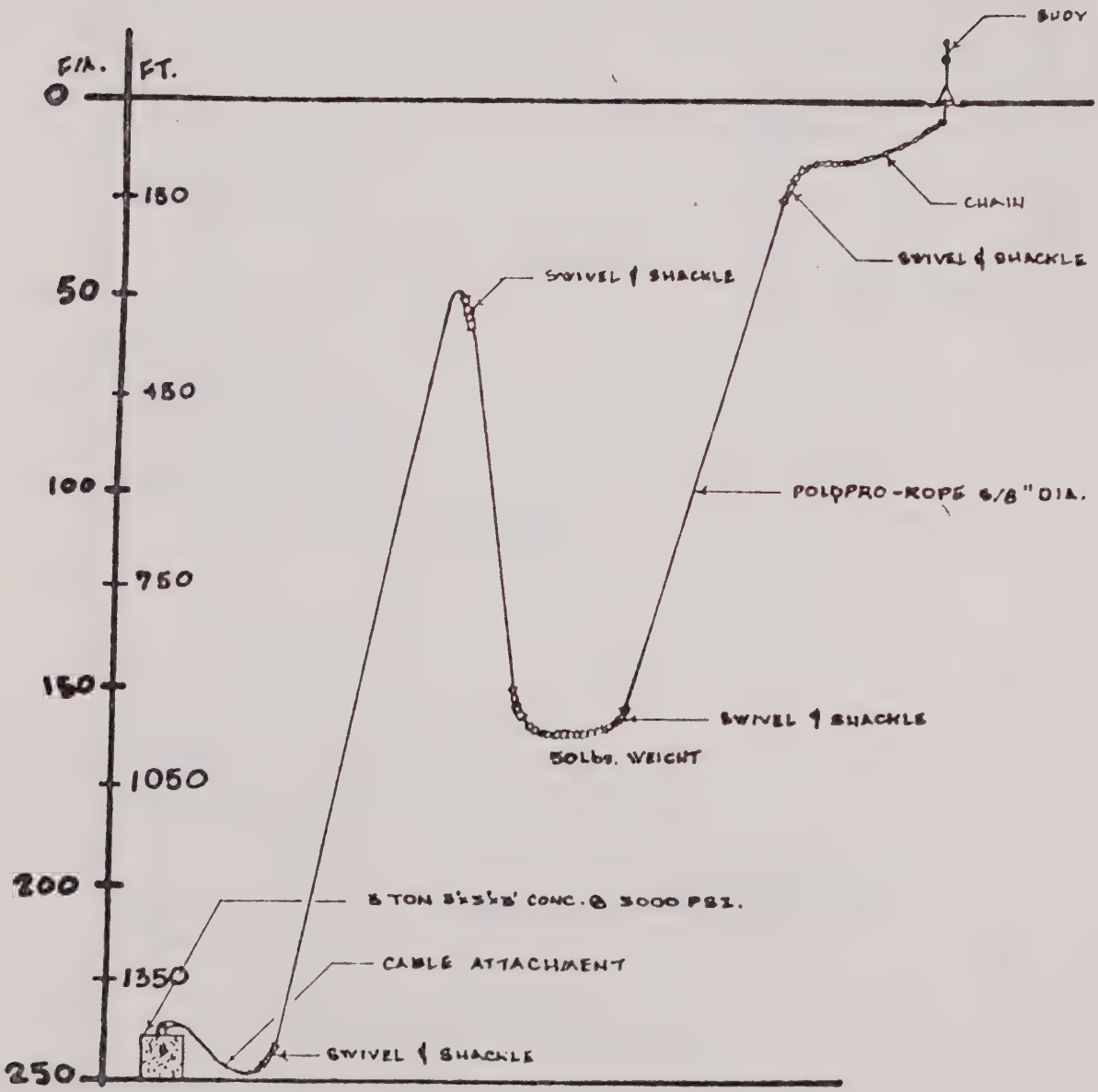


Figure 6. Hawaii Fish and Game FAD.

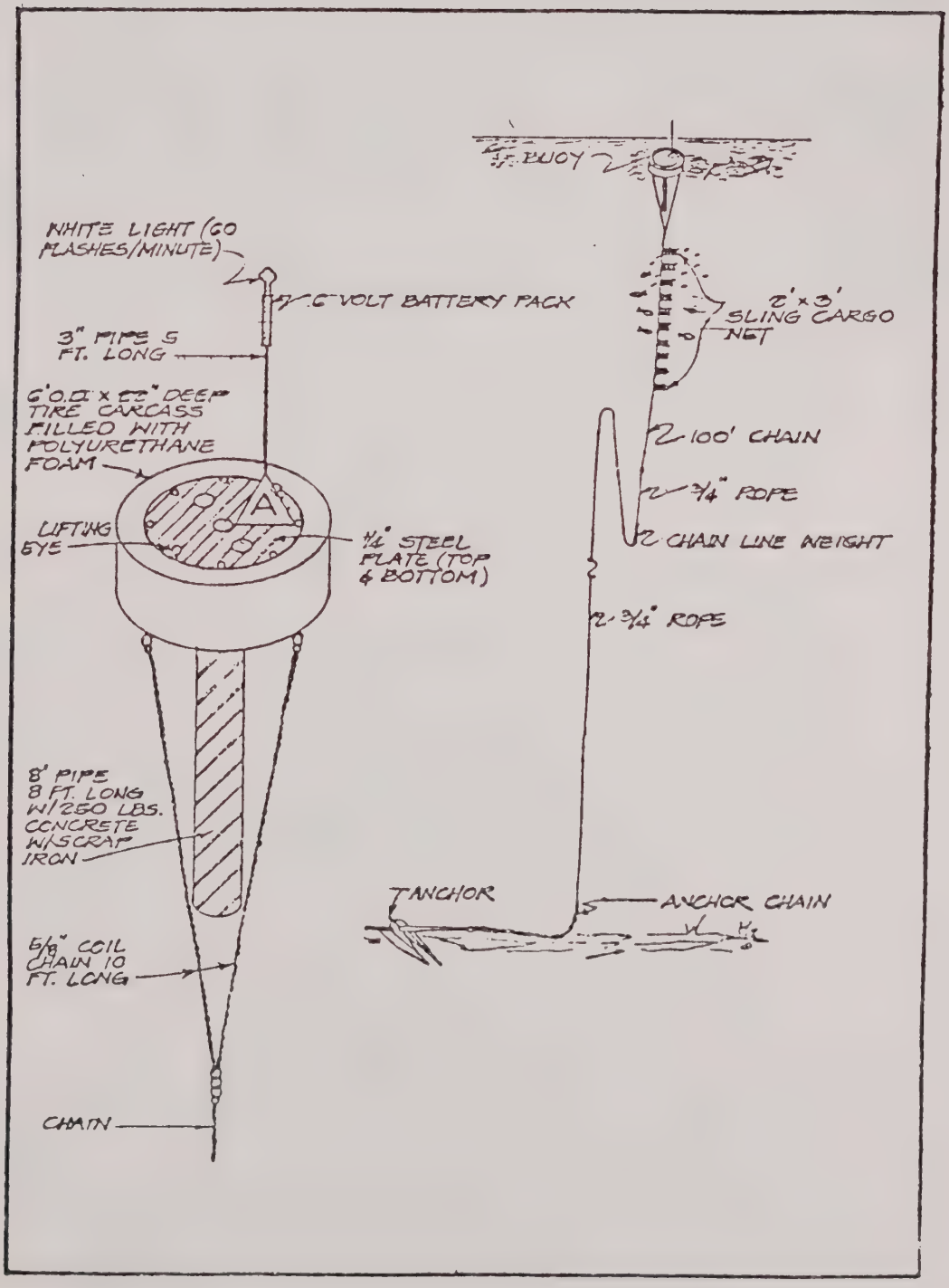

BUOY
WHITE LIGHT (60 FLASHES/MINUTE)
6 VOLT BATTERY PACK
2' x 3' SLING CARGO NET
3" PIPE 5 FT. LONG
6' O.D. x 22" DEEP TIRE CARCASS FILLED WITH POLYURETHANE FOAM
100' CHAIN
3/4" ROPE
CHAIN LINE WEIGHT
LIFTING EYE
1/4" STEEL PLATE (TOP & BOTTOM)
3/4" ROPE
8' PIPE 8 FT. LONG W/250 LBS. CONCRETE W/SCRAP IRON
ANCHOR
ANCHOR CHAIN
5/8" COIL CHAIN 10 FT. LONG
CHAIN

Figure 7. Hawaii Fish and Game mooring details.

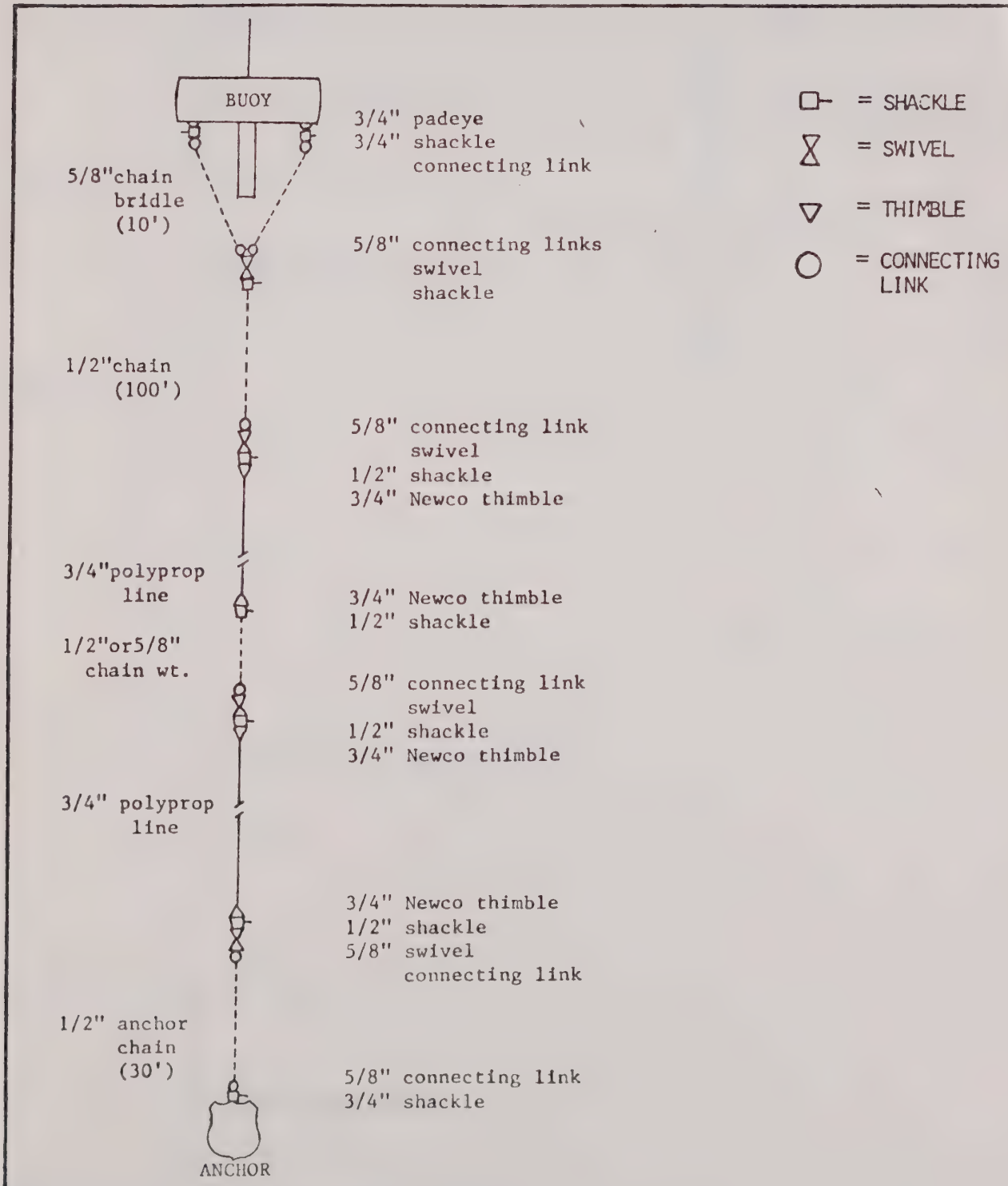
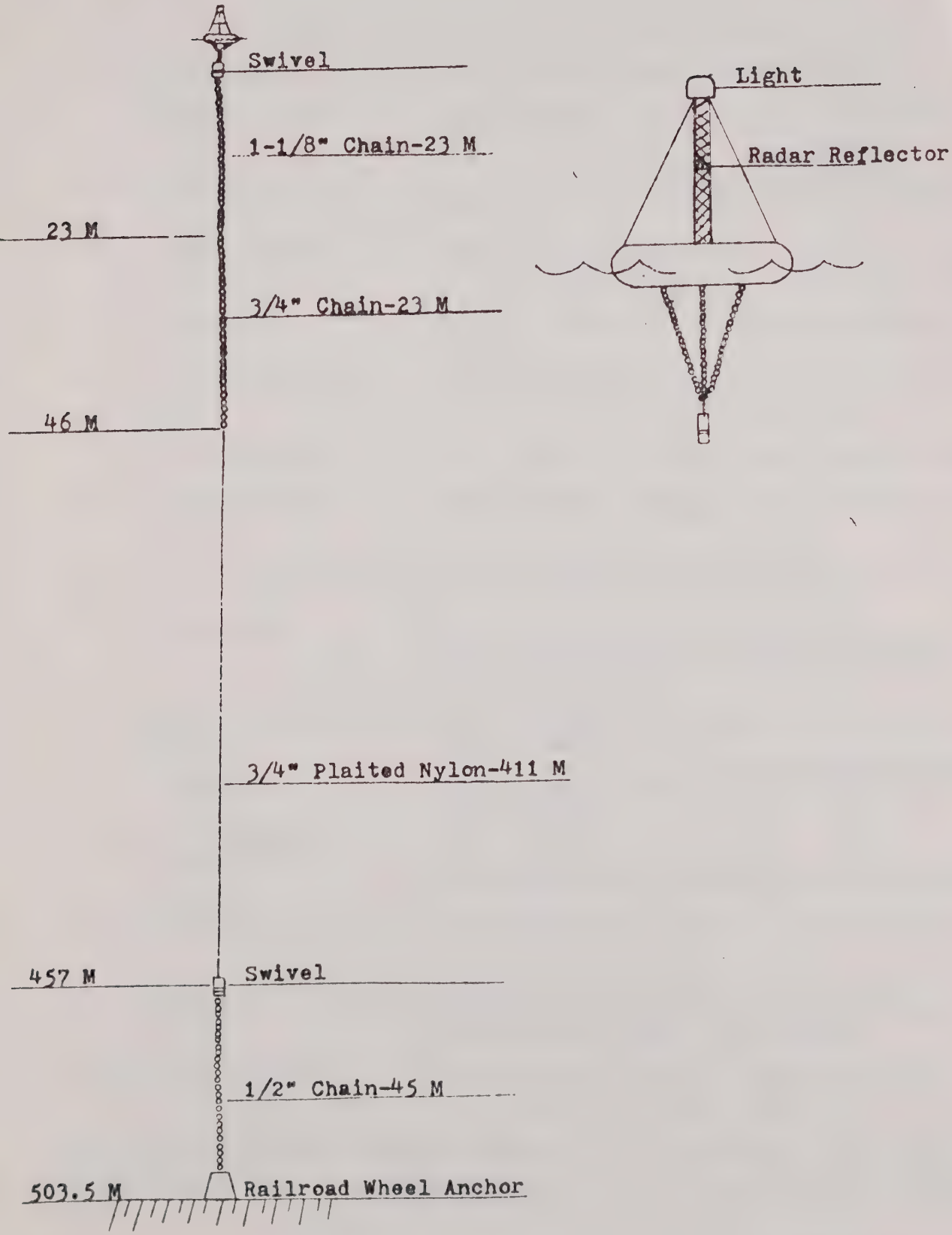


Figure 8. Suggested ideal mooring.



ADDRESSEES - FISH AGGREGATING DEVICES WORKSHOP

1.	Mr. Ian Blogg	9407 E. Marginal Ways, Seattle, WA 98108
2.	Dr. Richard E. Brock	Hawaii Institute of Marine Biology, UH, P. O. Box 1346 Kaneohe, HI 96744
3.	Mr. Patrick Bryan	Office of Marine Resources, Government of A.S. P.O. Box 6 Pago Pago, American Samoa 96799
4.	Mr. Doyle E. Gates	Western Pacific Program Office, Southwest Region, P. O. Box 3830, Honolulu, HI 96812
5.	Mr. Mike Gawel	East West Center, E-W Center Box 1806, Honolulu, HI 96848
6.	Mr. Richard M. Howell (Rich)	Guam Fishermen's Cooperative Assn., P.O. Box 24023, GMF, Agana, Guam, Mariana Islands 96921
7.	Mr. Gerson Jackson	Marine Resources Division, Kosrae, Micronesia 96944
8.	Mr. Alvin Katekaru	Hawaii Division of Fish and Game, 1151 Punchbowl Street, Honolulu, HI 96813
9.	Mr. Joseph Matanane (Joe)	Bureau of Budget and Management Research, Office of the Governor, Agana, Guam 96910
10.	Mr. David Nada	Pacific Tuna Development Foundation, Hawaii State Department of Planning and Economic Development, P. O. Box 2359, Honolulu, HI 96804
11.	Mr. Robert T. Nishimoto (Bob)	Hawaii Division of Fish and Game, 1151 Punchbowl Street, Honolulu, HI 96813
12.	Mr. Toshiro Paulis	Trust Territory of the Pacific Islands P.O. Box 1600 Marine Resources Office, Koror, Palau, Caroline Islands 96940
13.	Mr. Ramon ~~Echebei~~ Rechebei	Marine Resources Division, Trust Territory of the Pacific Islands, Saipan, Mariana Islands 96950
14.	Mr. Douglas Souter	Living Marine Resources, Inc., 7169 Construction Court, San Diego, CA 92121
15.	Mr. Joaquin P. Villagomez (Jack)	Marine Resources Development, Office of the Governor, Commonwealth of the Northern Mariana Islands, Saipan, Mariana Islands 96950
16.	Dr. Izadore Barrett Center Director	Southwest Fisheries Center, F/SWC, NMFS, NOAA, P. O. Box 271, La Jolla, CA 92038

2/11/81 Two copies to Chuck Johnston to forward to Yap--interested in constructing 5 buoys

2/17/81 Copy to Bill Puleloa, Fisheries Officer, Majuro, Marshall Islands , TT w/DO lette

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

December 31, 1980

Multiple addressee letter
(see attached list)

Enclosed please find Fish Aggregating Devices (FAD) Workshop report.

Sincerely yours,

Richard S. Shomura
Director, Honolulu Laboratory

Enclosure